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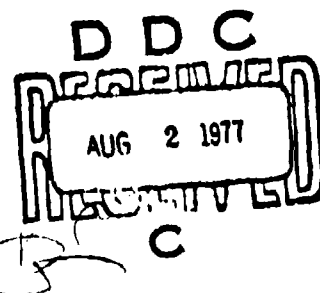
# Aircraft Alerting Systems Criteria Study

## Volume I

### Collation and Analysis of Aircraft Alerting System Data



D6-44199  
May 1977



FINAL REPORT

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**FEDERAL AVIATION ADMINISTRATION**  
**Systems Research & Development Service**  
**Washington, D.C. 20590**

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16. Abstract Several recent studies, performed to develop optimum alerting methods for new alerts that had to be retrofitted to existing aircraft, identified as major alerting system problems the proliferation of alerting systems and the inconsistent application of alerting concepts in current commercial transport aircraft. The objective of this study was to address these problem areas in the following manner: (1) refine and augment the stimuli response data collected under the previous studies, (2) provide test plans for additional stimuli response tests required to complete the stimuli response data base, (3) provide tabulations of the alerting methods and alerting requirements used on current commercial transport aircraft, (4) develop a method for prioritizing alerting functions and prioritizing the alerting functions accordingly, (5) note conflicts between current alerting requirements and the prioritized list of alerts, and (6) provide recommendations for standardization of alerting functions/methods. The output includes a collation of human factors data pertinent to alerting systems, cursory test plans for obtaining missing human factors data required to complete definition of and validate the standards recommended for alerting systems, criteria for alert priority levels, an example tabulation of alerts that might fall within each priority level, and recommended methods of annunciating the alerts within each priority level.		
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# METRIC CONVERSION FACTORS

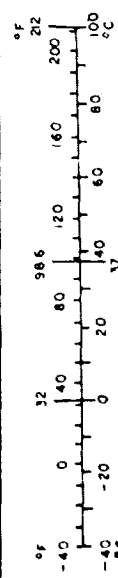
## Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	6.5	square centimeters	cm <sup>2</sup>
ft <sup>2</sup>	square feet	0.09	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.8	square meters	m <sup>2</sup>
mi <sup>2</sup>	square miles	2.6	square kilometers	km <sup>2</sup>
	acres	0.4	hectares	ha
<b>MASS (weight)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons	0.9	tonnes	t
	(2000 lb)			
<b>VOLUME</b>				
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft <sup>3</sup>	cubic feet	0.03	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.76	cubic meters	m <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

\* 1 in. = 2.54 centimeters exactly. All other metric conversions are not exact, but are rounded to the nearest millimeter, gram, liter, or degree Celsius.

## Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	1.2	square yards	yd <sup>2</sup>
km <sup>2</sup>	square kilometers	0.4	square miles	mi <sup>2</sup>
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	
<b>MASS (weight)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
<b>VOLUME</b>				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m <sup>3</sup>	cubic meters	35	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.3	cubic yards	yd <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F





## FOREWORD

This final technical report covers work performed under the third phase of FAA contract DOT-FA73WA-3233, "Collation and Analysis of Aircraft Alerting Systems Data." The study was initiated to establish an alerting philosophy for aircraft cockpit alerting systems.

The contract sponsor was FAA Systems Research and Development Service (SRDS) and performed by the Boeing Commercial Airplane Company. Technical guidance for this contract was provided by Mr. John Hendrickson, ARD-743, the contract monitor.

Study conduct covered the period January 1976 through November 1976. The performing organization was Systems Technology-Crew Systems, of the Boeing Commercial Airplane Company, Seattle, Washington. W. D. Smith was program manager, J. E. Veitengruber was principal investigator, and G. P. Boucek was the signal/response analyst.

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UNANNOUNCED	<input type="checkbox"/>
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## SYNOPSIS

The purpose of this study was to develop preliminary design guidelines and standards for aircraft alerting systems.

The scope of the study encompassed five major tasks. Task I consisted of tabulating current alerting methods and deciphering factors causing proliferation of the alerts. In Task II, criteria for prioritizing the alerting functions were developed and applied. In Task III, standards and regulations applicable to alerting system standards were reviewed and compared with the results of Task II to identify conflicts. Tasks IV and V consisted of broadening the stimuli response data base developed in a previous study and defining tests required to obtain missing data.

Preliminary alerting system design guidelines (standards) were developed from the results of each task. The guidelines included: (1) criteria for four alert priority levels, (2) a tabulation of the alerts that might fit the criteria for the two highest priority levels, (3) an example tabulation of alert priorities within each alert category, and (4) recommended methods of annunciating the alerts within each priority category. In addition to these guidelines, cursory test plans for obtaining the missing human factors data required to complete definition of and validate these guidelines are also provided.

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## ABBREVIATIONS & SYMBOLS

ACFT	Aircraft
ADI	Attitude Director Indicator
AG	Attention Getter
ALT	Altitude
AMB	Amber
A/P	Autopilot
APU	Auxiliary Power Unit
ATM	Air Turbine Motor
A/T	Auto Throttle
ASS ALT	Assigned Attitude
BLK	Black
BLU	Blue
BRT	Bright
CADC	Central Air Data Computer
CAS	Collision Avoidance System
CONT	Continued
CONFIG	Configuration
CSD	Constant Speed Drive (Electrical Generator)
CWS	Control Wheel Steering
dB	Decibels
DME	Distance Measuring Equipment
EGT	Exhaust Gas Temperature
EMER	Emergency
ENG	Engine
EVAC	Evacuation
FAR	Federal Aviation Regulation
FE	Flight Engineer
FL	Flashing
FLT INST	Flight Instrument
ft-L	Foot Lamberts
GRD PROX	Ground Proximity
GRN	Green
HORIZ	Horizontal
HSI	Horizontal Situation Indicator
Hz	Hertz
IAM	Independent Altitude Monitor
IATA	International Air Transport Association
IDG	Integrated Drive Generator (Electrical)
ILS	Instrument Landing System
INS	Inertial Navigation System
LDG	Landing
LTS	Lights
MDA	Minimum Descent Altitude
ORN	Orange
PRESS	Pressure
QUAN	Quantity

## **ABBREVIATIONS & SYMBOLS (Cont)**

<b>RA</b>	Radio Altitude
<b>RTCA</b>	Radio Technical Commission for Aeronautics
<b>SAE</b>	Society of Automotive Engineers, Inc.
<b>SAS</b>	Stability Augmentation System
<b>SELCAL</b>	Selective Call System (Company Communication)
<b>STAB</b>	Stabilizer
<b>SYST</b>	System
<b>VOR</b>	Very High Frequency Omnidirectional Radio Range
<b>WHT</b>	White
<b>YEL</b>	Yellow

## 1.0 INTRODUCTION AND SUMMARY

### 1.1 INTRODUCTION

This contract is the third of a series of contracts that have evolved from studies of independent altitude monitor requirements to this, a study of cockpit alerting system problems. Under the first contract, "Development of an Independent Altitude Monitoring (IAM) System Concept," sensor principles and control-display-alerting methods for IAM systems were studied. That study indicated that additional research was required to assess the effectiveness of various IAM control-display-alerting methods. A second contract was issued to study these alerting problems. A summary of alert philosophies used in current aircraft and IAM systems, a data base of currently used alerting characteristics including stimulus response characteristics, three recommended IAM alerting methods for each category of aircraft (light private aircraft, commercial transports, etc.), and guidelines for developing or completing development and implementation of an IAM system were produced. The proliferation of alerting devices in the cockpit, the inconsistent application of alerting concepts in current commercial transport aircraft, nonadherence to existing alerting system standards because they were outdated, and the need for a set of design objectives and design guidelines acceptable to all commercial transport aircraft operators and manufacturers became evident in this second study. The current contract therefore was issued to study the entire cockpit problem.

The objectives of this study were: (1) refine and augment the stimuli response data collected under the previous contract, (2) provide test plans for additional stimuli response tests required to complete the stimuli response data base, (3) provide tabulations of the alerting methods and alerting requirements used on current commercial transport aircraft, (4) develop a method for prioritizing alerting functions and prioritizing the alerting functions accordingly, (5) note conflicts between current alerting requirements and the prioritized list of alerts, and (6) provide recommendations for standardization of alerting functions/methods. The results of this study represent a first cut at design objectives and design guidelines for alerting systems in new aircraft. Considerable more refinement, testing, and analysis of the hardware/implementation impact of the alerting system concepts that resulted from this study are required.

### 1.2 SUMMARY

At the beginning of this study, numerous inconsistencies in the alerting concepts applied to each type of aircraft were known to exist (ref. 1). Specific inconsistencies in the aural alerts were known and similar inconsistencies in the visual alerts were suspected. These suspicions were proven to be correct. In addition to verifying that these inconsistencies existed and the type of inconsistencies that were occurring, the study showed that a proliferation of alerts occurred in the latest generation of aircraft. Analyses of the type of alerts involved in the proliferations revealed the following facts:

- Each new aircraft has incorporated more alerting functions than previous similar aircraft because of:
  1. Differences in the operators' alerting system utilization philosophies
  2. Differences in the airframers' cockpit design philosophies
  3. Additional regulatory requirements

4. Increased size of the later vintage aircraft
  5. Use of more complex systems to save weight
- Number of warning-type alerts used in commercial turbojet transport aircraft nearly doubled in the transition from narrow body to wide body aircraft.
  - Number of caution- and advisory-type alerts used in commercial turbojet aircraft has increased substantially with each new aircraft design.
  - A trend exists toward providing the crew with more detailed subsystem information (more lights and bands) so that the pilots can try to resolve malfunctions in flight and record better maintenance data.
  - Among the narrow body aircraft no significant change in the number of alert lights, aural, flags or bands occurred. Aircraft size, types of operation, and vintage had little effect on the design of the alerting systems in these aircraft.
  - Wide body aircraft use substantially more alert lights, flags, and aural than narrow body aircraft.
  - A trend exists toward more multifunctioning of the alerting devices.
  - The number of warnings increased primarily because of the red flags required to annunciate the new failure modes of more complex autopilots and avionics on board wide body aircraft.
  - Amber and yellow lights are being used more extensively with each new generation of aircraft to annunciate detailed subsystem operations.
  - A trend toward annunciating more positive GO and SAFE conditions with green light exists.
  - White-lighted pushbuttons are being used more extensively in place of toggle switches in each new generation of aircraft.
  - Discrete alerts lights are being used to replace traditional color bands.
  - No consistent utilization philosophy has been applied to the aural alerts, not even within any operator's or airframer's line of aircraft. Somewhat of a standard appears to have been established for only 5 of the 9 to 17 aural alerts used on each aircraft today.
  - The number of aural alerts is increasing.
  - Most rapid growth in the number of subsystems alerts has occurred in the electrical and automatic flight control systems. Negligible growth has occurred in the air conditioning, altitude alert, APU, communications, emergency equipment, flight instrument, air data, fuel, and powerplant systems.
  - Master caution and/or master warning systems are used in all two-man-crew aircraft but in only a few three-man-crew aircraft.

- Master warning systems are activated by only a small percentage of the red lights, approximately half of the red lights in the cockpit. Similarly, master caution systems are activated by only about half of the amber and yellow lights in the cockpit.
- Only a very small percentage of the aural alerts, less than 7%, activate the master warning system.
- Alert prioritization currently is not used on any aircraft except late production models of the 737 and a few 727s.
- Inhibiting of subsystem fault alerts is not used on any aircraft except the DC-10.
- The correlation between the type of alert and type of checklist applied to each situation is poor.

In addition to these facts, most pilots agreed with the following issues:

- The number of alerts, especially the number of aural alerts, needs to be reduced.
- Most aural alerts, as currently designed, are too loud.
- Noncritical alerts should be inhibited during high workload periods, such as takeoff and flare/landing.
- Selected alerts should be prioritized.
- A unique audio, visual, or combination audio-visual method of alerting should be associated with each priority to provide an instantaneous assessment of the situation's criticality.
- A definite correlation between the type of alert and the type of checklist or procedure applied to each situation should be established. (Note: This does not imply that a checklist is required for each alert.)

A study of the human factors data relevant to the design of alerting systems was then conducted (ref. 2). The following *preliminary* guidelines resulted:

- High-priority alerts should be located no more than  $15^{\circ}$  from the pilot's normal line of vision. Similarly caution signals should be located no more than  $30^{\circ}$  from the pilot's line of vision. Normal line of vision is defined as the line between the pilot's eye reference point and the center of the ADI.
- High-priority visual alerting devices should be no less than  $1^{\circ}$  visual angle in size. Secondary visual alerts should be no less than  $0.5^{\circ}$  visual angle in size.
- High-priority visual signals should have a brightness capability of at least 150 ft-L and be twice as bright as secondary displays. Secondary visual alerts should have a brightness of at least 15 ft-L and be at least 10% brighter than lesser priority displays in the same area.
- Automatic brightness adjustment for varying ambient light conditions should be provided.

- High-priority (LEVEL 1) visual alerts should flash.
- Each aural alerting signal should be composed of two or more widely separated frequencies in the range from 250 to 4000 Hz.
- The maximum intensity of aural alerts should be 15 dB above threshold noise level or halfway between the threshold noise level and 110 dB, whichever is less. Threshold equals level at which 50% of the alerts are detected.
- Automatic intensity adjustment for varying ambient noise conditions should be provided.
- Aural alerts should be presented dichotically to the pilot's dominant ear. If dichotic separation is not possible, the source of aural alert signals should be located 90° from the primary sources of interfering noise or messages.
- Intermittent sounds should be used for aural alerts.
- Aural alerting messages (voice annunciations) should be preceded by an identifier to which the pilot is more than normally sensitive.
- Voice warnings should be used only to annunciate highest priority situations.
- Voice warning messages should be constructed of short sentences of polysyllabic words.
- Pilots should be familiar with all voice warning messages.
- Use of tactile alerts should be minimized.

A method of prioritizing the alerting functions was then sought. Criteria defining the priority categories are presented in table 1. These priority categories were applied to the alerting systems data collected at the beginning of this study, i.e., the alerts were categorized as shown in section 2.3.2. During application of these alert priority criteria, it was noted that the LEVEL 3 and LEVEL 4 alerts were very sensitive to the peculiar design characteristics of each aircraft. Thus, it was recommended that alert priority guidelines be established only for the LEVEL 1 and possibly some LEVEL 2 alerts, and that the airframe manufacturers and operators define the LEVEL 3 and LEVEL 4 priorities for each type of aircraft.

The results of the alerting systems data analyses, the pilot surveys, the human factors guidelines study, and the alert prioritization study were combined to formulate preliminary recommendations for standardization of alerting methods. A synopsis of the proposed guidelines for alerting methods is presented in table 1. Complete listing of the recommended guidelines is presented in section 2.5.1.

Table 1 Guidelines for Standardization of Alerting Functions and Methods

Level	Condition	Criteria	Alert system characteristics		
			Visual	Aural	Tactile
1	Emergency (warning)	Emergency operational or aircraft systems conditions which require <u>immediate corrective or compensatory action by the crew.</u>	Centrally located alphanumeric readout	Discrete sounds, or attention getting tone plus voice	Stick shaker (if required)
2	Abnormal (caution)	Abnormal operational or aircraft systems conditions which require <u>immediate crew awareness and require corrective or compensatory crew action.</u>	Centrally located alphanumeric readout	Attention getting tone	None
3	Advisory	Operational or aircraft systems conditions which require <u>crew awareness</u> and may require crew action.	Centrally located alphanumeric readout	None	None
4	Information	Operational or aircraft systems conditions which require cockpit indication but not necessarily as part of the integrated warning system.	Discrete lights (green, blue and white)	None	None

The recommended guidelines should be interpreted as (1) preliminary, not final, design guidelines, and (2) design objectives, not minimum performance standards. At this time, the recommended design guidelines are only partially substantiated by quantitative data. Additional testing to derive directly applicable human factors data, additional comparative testing of elements of alerting systems, additional comparative testing of full alerting system concepts and an analysis of the hardware/implementation impact of these concepts are required to complete and validate the proposed design guidelines.



## 2.0 TECHNICAL REPORT

The methods of analysis used in studying this alerting system problem, the data used in and resulting from these analyses, and the conclusions derived therefrom are presented in this section. This study was divided into five tasks:

- Tabulating current alerting methods and requirements
- Establishing alerting function requirements
- Developing a method for categorizing/prioritizing alerting functions
- Developing human factors design guidelines for alerting systems
- Developing recommendations for standardization of alerting functions and methods

The first task consisted of selecting a baseline aircraft configuration for each basic type of turbojet transport used in the U.S., tabulating the physical characteristics of all alerting functions in these aircraft, and analyzing the implementation differences between the various types of aircraft. The second task consisted of reviewing applicable standards, accident data, maintenance and operations records concerned with current alerting systems problems, and checklists in an attempt to establish functional requirements for alerting systems. The third task consisted of numerous discussions with pilot organizations to obtain a consensus of pilot opinions on how an optimum aircraft warning system would be designed and then correlating the results of these meetings with the results of the requirements analyses to develop a rationale for categorizing and prioritizing the alerting functions. In the fourth task, a literature search for human factors data applicable to alerting systems was performed, a survey of human factors data requirements was made, and a set of test plans aimed at obtaining the missing data were developed. The requirements, categorization/prioritization rationale, and existing human factors design guidelines were then combined to develop recommendations for standardization of alerting methods. The details of each of these subtasks are presented in the following sections.

### 2.1 CURRENT ALERTING METHODS

A data base consisting of tabulations of the characteristics of the alerting subsystems in each basic type of commercial turbojet transport airplane was established to analyze differences between various types of aircraft and to correlate pilot comments with specific design features. From these analyses, alerting system characteristics that appear to be either good and should be retained, or bad and should be avoided were discerned. Descriptions of the data base, analyses, and results of this effort follow.

#### 2.1.1 BASELINE AIRCRAFT CONFIGURATIONS

Aircraft types used by each major U.S. and European airline were tabulated as shown in table 2. The quantity of each type of aircraft operated by several of these airlines was also tabulated. From this tabulation, aircraft from several airlines operating a broad range of aircraft and a significant number of each type of aircraft were selected to use as baseline configurations. The airlines and aircraft selected for this purpose are specified in table 3. Airbus (A300) and Concorde data also were sought but were not available in sufficient detail to be useful to this study.

Table 2 Aircraft Types Used by Airline

AIRLINE	707/720	727	737	747	DC 8	DC 9	DC 10	L-1011	BAC-111	A-300	CON - CORDE
AMERICAN	X	X		X	X		X				
BRANIFF		X		X	X						
CONTINENTAL	X	X		X			X				
DELTA		X (62)		X (3)	X (34)	X (62)		X (18)			
EASTERN		X			X	X		X			
NATIONAL		X		X			X				
NORTHWEST	X (11)	X (55)		X (18)			X (22)				
PAN AMERICAN	X (78)	X (15)		X (30)							
TWA	X (72)	X (74)		X (12)		X (10)		X (18)			
UNITED		X (146)	X (46)	X (18)	X (33)		X (37)				
WESTERN	X (22)	X (21)	X (26)				X (6)				
AIR CANADA		X		X	X	X		X			
ALITALIA				X	X	X	X				
ALLEGHENY						X (43)			X (31)		
BRITISH AIRWAYS	X			X				X	X		X (5)
CANADIAN PACIFIC AIR		X	X	X	X						

DATA SOURCE:

WORLD COMMERCIAL AIRCRAFT INVENTORY  
(DATA AS OF JUNE 30, 1975)  
DOUGLAS AIRCRAFT COMPANY

NOTE

1. X INDICATES AIRLINE USES THIS TYPE AIRCRAFT
2. ( ) INDICATES NUMBER OF AIRCRAFT OF THIS TYPE OPERATED BY THE AIRLINE.

Table 2 Aircraft Types Used by Airline (Cont)

AIRLINE	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	A-300	CON - CORDE
IBERIA		X		X	X	X	X				
IRAN AIR	X	X	X	X							
JAL		X		X	X		X				
KLM				X	X	X	X				
LUFTHANSA	X (19)	X (29)	X (28)	X (5)			X (9)			X (3)	
AIR FRANCE	X	X	X	X						X (6)	X (4)
OLYMPIC	X	X		X							
PACIFIC WESTERN	X	X	X								
SAA (S. AFRICA)	X	X	X	X							
SABENA	X	X	X	X			X				
SAS				X	X	X	X				
SAUDIA	X										
SINGAPORE	X		X	X							
SWISS AIR				X	X	X	X				
VARIG	X	X	X	X							

DATA SOURCE:

WORLD COMMERCIAL AIRCRAFT INVENTORY  
(DATA AS OF JUNE 30, 1975)  
DOUGLAS AIRCRAFT COMPANY

NOTE: 1. X INDICATES AIRLINE USES THIS TYPE AIRCRAFT  
2. ( ) INDICATES NUMBER OF AIRCRAFT OF THIS  
TYPE OPERATED BY THE AIRLINE.

**Table 3 Aircraft Types Selected for Data Base**

Aircraft	Baseline Airline(s)
707-720	TWA
727	TWA
737	Western
747	TWA
DC-8	United
DC-9	TWA
DC-10	Western
L-1011	TWA
BAC-111	Allegheny

Ideally all aircraft used in developing the baseline configuration data would have been from one airline to eliminate airline-to-airline differences from the data. A mixture of airlines had to be used because no single airline operated all the aircraft covered by the study. This mixture of aircraft from several airlines caused small biases in the comparative data that reflect airline differences, not basic aircraft differences. Comparisons of the alerting system features in various aircraft from one airline should be valid, but comparisons between aircraft from several airlines must be made with cognizance of these differences. In general therefore, *comparisons of the aircraft alerting systems data must be analyzed with caution.*

### **2.1.2 ALERTING FUNCTIONS**

Aircraft system malfunctions and operational situations for which alerts are provided vary as a function of the size of the aircraft, type of operations for which the aircraft is used, and cockpit design features specified by the first major customer of each new aircraft type. As an example, a four-engine 747 might be expected to have approximately twice as many alerts as a two-engine 737 because both aircraft were designed during the same time period (1964-1968). However, the 747 has substantially more than twice the number of alerts of the 737. The differences are due to the groundrules to which the cockpits were designed:

- 737      Significant automation of systems controls to be compatible with the workload capabilities of a two-man crew
- 747      Maintain similarity with 707 cockpit to allow easy transition of senior 707 crews to the 747

Because these variations are not predictable, a detailed tabulation of the type of alerts used for each function in these aircraft was constructed.

The alerting function tabulations specify the number and type of alerts used for each function. A sample of this tabulation is provided in figure 1. The complete tabulation is provided in appendix A.

Three new terms requiring definition have entered the discussion now, i.e., alert, alerting function, and alerting devices. An alert is the activation of any aural alarm, indicator light, or flag. The term alert includes the situation wherein a pointer or tape on an analog indicator displays a parameter value in the green, yellow, orange, or red band range. Alerting functions are the operational situations or aircraft system conditions annunciated to the crew. More than one alerting function generally exists for each basic alerting situation. The 727, for example, has three alerting functions for engine fire warning. Alerting devices are the physical devices used to annunciate alerts. Note that a separate alerting device is not provided in the cockpit for each alerting function specified in the tabulation. In many cases, a specific alerting device will perform several alerting functions. An example of this type of situation is a multicolor light that illuminates green to indicate a system is ON and amber to indicate the system is armed or has malfunctioned. Therefore each aircraft type would in general have fewer physical alerting devices than alerting functions.

### 2.1.3 CHARACTERISTICS OF ALERTING SIGNALS

No consistent utilization philosophy has been applied to the alerting systems in the types of aircraft covered by this study. Even within each airframer's product line of aircraft and each operator's aircraft, numerous inconsistencies in the utilization of the alerting systems appear. These differences were analyzed by searching the alerting function tabulations for comparable alerting situations and noting the similarities or differences. The rationale behind obvious differences was then investigated. These observations were combined with analyses of several dissections of the data in the alerting function tabulations. In particular the alerting systems data were dissected to analyze the following characteristics of the alerts:

- Operational distribution
- Mechanical distribution
- Color distribution
- Aural alert applications
- Color of visual alerts associated with aural alerts
- Aircraft systems causing the proliferation of alerts
- Effects of a master caution and master warning subsystems on the overall alerting system design
- Effects of alert prioritization and inhibits on the overall alerting system design

The results of these analyses were then combined to develop guidelines for categorizing/prioritizing and designing alerting systems in future aircraft. Each of these analyses is discussed individually in the following sections.

Fire protection (sheet 1)

	Alerting function	Type of alert						
		707/727	727	737	747	DC-8	DC-9	DC-10
1	Master fire warning	Bell	2 fl red lts & bell	2 red lts & bell	2 red lts & bell	2 red lts & bell		2 red lts & bell
2	Fire extinguisher bottle discharged	4 amb lts	2 amb lts	3 amb lts	11 blu & 11 amb lts	4 amb lts	2 amb lts	8 amb lts
4	Engine and APU fire extinguishing system circuits ok							8 amb lts
5	Engine and APU fire detection system activated (test)		6 amb lts				6 amb lts	8 amb lts
6	Wheelwell fire detection system activated (test)							2 amb lts
7	Engine overheat			2 amb lts		4 yel/red bands	2 yel/red bands	3 red lts & 3 fl red lts
8	Engine overheat detection system circuits ok							2 wht lts
9	Galley smoke							1 fl amb lt (* 10) & tone
10	Galley overheat							1 amb lt (* 9) & tone
11	Nacelle/pylon overheat				4 yel/red bands			3 fl amb lts
12	Engine fire	4 red lts		3 red lts	4 red lts	4 red lts	4 red lts	3 red lts

\* Same as

Figure 1 Alerting Function Tabulation Example

### 2.1.3.1 Operational Distribution of Visual Alerts

Three alert classifications, defined in table 4, were established to allow analysis of differences in the operational distribution of visual alerts.

The term "bands" in these definitions includes radial arcs and "tick marks" on round dial and pointer displays, and linear bands on horizontal or vertical scale displays.

Some engineers contend that since instruments and advisory/status lights are often functionally interchangeable, all informational functions contained within the instruments also should be tabulated under the advisory/status alert classification. However, basic instruments do not pollute the visual environment of the alerting system in the same manner as extraneous lights or flags. Only the parameter limit information (bands) on the instruments was considered to have a significant impact on the visual effectiveness of the alerting system. Thus the basic informational functions of the instruments were not included in these analyses.

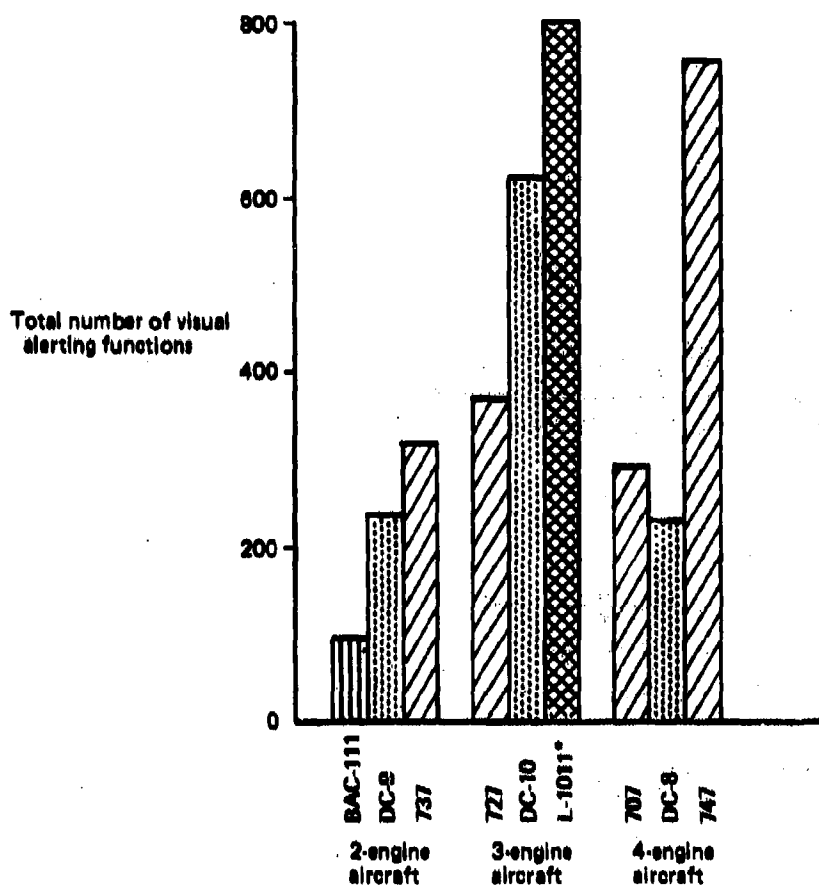
Figures 2 and 3 specify the total number of alerting functions on these aircraft and the historical application of these alerts. Figures 4 and 5 specify the number of visual alerting functions on each basic type of aircraft that fall within each of these classifications and the ratio of visual alerting functions in each classification. These data are also presented in tabular form in appendix B (tables B-1 and B-2).

Analyses of these data for alerting system differences as a function design vintage, aircraft size, and types of usage were made. The number of engines on these aircraft was used to group the aircraft into usage categories. These usage categories were selected because, in general, two-engine aircraft are used on short-haul operations, three-engine aircraft are used on medium-range operations, and four-engine aircraft are used on long-range operations. These categories also conveniently provide groups of aircraft with a similar number of onboard systems, e.g., same number of hydraulic systems.

Figures 2 and 3 illustrate that at least among the two-engine aircraft, the number of visual alerting functions increased with each new aircraft type. The question that arises is whether this increase was due to an increase in the number of regulatory requirements or basic philosophical differences between the manufacturer's cockpit designers. A quick survey of the FARs indicated that a significant number of new regulations that affected alerting systems evolved between the BAC-111 and 737 design eras. The DC-9 was designed 2 years after the BAC-111 and the 737 was designed 4 years after the BAC-111; however, not all this increase was due to new regulatory requirements. Thus the growth in the number of alerting functions as a function of time among the two-engine aircraft is attributed to both differences in the airframers' cockpit design philosophies and new regulatory requirements.

*Table 4 Alert Type Classifications*

Classification	Alert types included in classification
Warning	Red lights, red or orange flags and red bands
Caution	Amber or yellow lights, flags or bands
Advisory/status	Green, blue or white lights, flags or bands



\*L-1011 utilizes lighted pushbutton switches with color modes to indicate switch state in place of toggle switches.

*Figure 2 Number of Visual Alerting Functions on Each Basic Aircraft Type*

Among the three-engine aircraft, a similar trend toward increasing the number of alerting functions was noted. In general, the 727, DC-10, and L-1011 have the same number of systems of each type, e.g., all have three main electrical generator systems. However, in a few cases, such as air conditioning, the number of channels was increased from two for the 727 to three for the DC-10 and L-1011. Their difference in size (narrow body 727 versus wide body DC-10 and L-1011) may have influenced these statistics. The increased use of late technology and more complex systems may also have attributed to the growth in the number of alerting functions. As an example, on McDonnell Douglas aircraft, all narrow body aircraft had a mechanical flap blow-back system; the DC-10, for weight-savings reasons, utilized a more complex but lighter electronic flap blow-back system. Two additional annunciator lights were required with the electronic system. Additionally, between the 727 and DC-10/L-1011 design eras, a significant number of regulatory requirements were added. The interaction between these factors is not known; the increase in the number of visual alerting functions among three-engine aircraft must be attributed to all these factors.



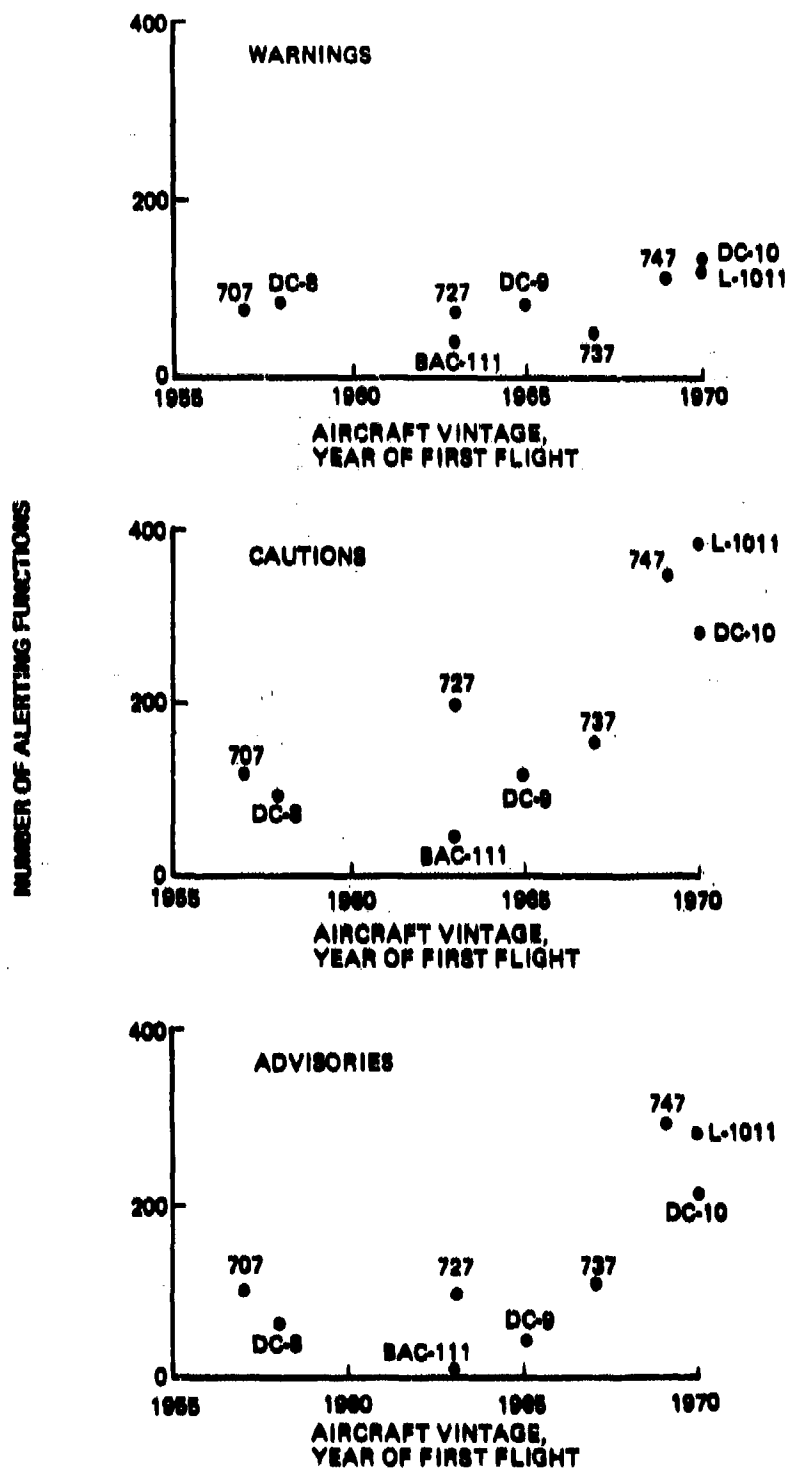
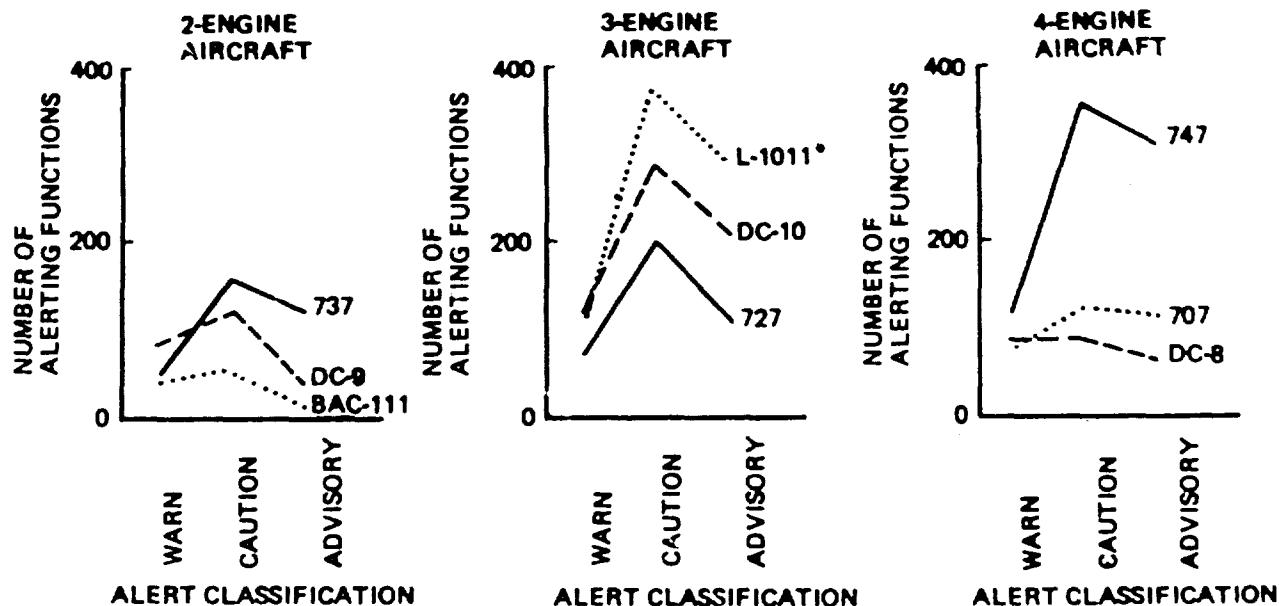
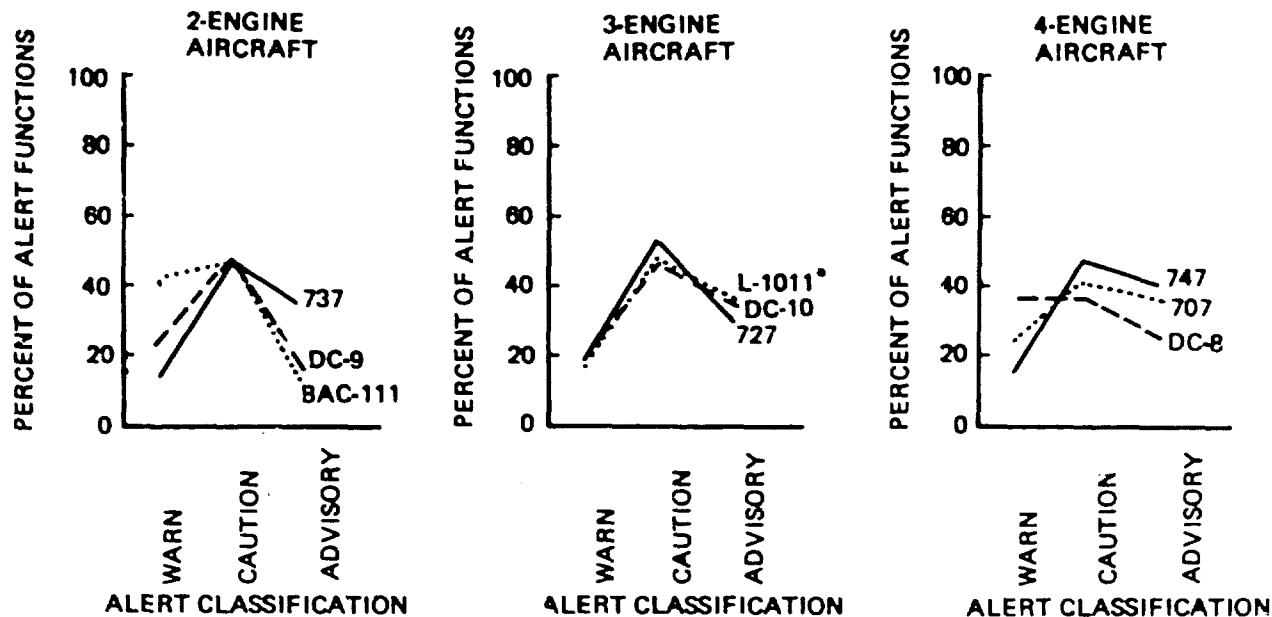


Figure 3 Application of Alerts as a Function of Operational Significance and Aircraft Vintage



\*L-1011 utilizes lighted pushbutton switches with color modes to indicate switch state in place of toggle switches.

Figure 4 Operational Distribution of Visual Alert Functions



\*L-1011 utilizes lighted pushbutton switches with color modes to indicate switch state in place of toggle switches.

Figure 5 Percentage Distribution of Visual Alert Functions Among Operational Classifications.

The 707 and DC-8 were designed with approximately the same number of alerting functions. The 747, which was designed 12 years later, emerged with a significant increase in the number of alerting functions. In general, the 747 required more channels of each type of system than the 707 or DC-8. This was primarily because of its massive size as compared to the 707 or DC-8. McDonnell Douglas claims that a significant portion of the increase in the number of alerting functions on the wide body aircraft is attributable to the application of modern weight-savings technology. More complex but lighter systems were often used to save weight on the wide body aircraft. The wide body aircraft also had to contend with a significant number of new regulatory requirements that emerged between 1957 and 1969. Therefore, the cause of the increase in the number of alerting functions among the four-engine aircraft can be attributed to the size of aircraft, use of more complex systems on the wide body aircraft to save weight, and additional regulatory requirements.

In the foregoing discussion it was concluded that the number of alerting functions in the cockpit increased as a function of time. The question that arises is "what type of alerts were added and how did the alert distributions change with these additions?" The data presented in figures 4 and 5 for two-engine aircraft indicate that the DC-9 and 737 designs incorporated substantially more caution and advisory alerts than the BAC-111. All three aircraft rely approximately equally on caution-type alerts as shown by the percentage distribution curves. However, the BAC-111 alerting system design relies heavily on warning functions whereas the 737 relies heavily on advisory functions.

Among the three-engine aircraft, a significant growth in the number of alerting functions from the 727 to the DC-10 and L-1011 is again noted in these data. However, the ratio of warnings-to-cautions-to-advisories did not change appreciably.

Note that many of the advisory functions in the L-1011 data have no equivalent alerting function in the 727 or DC-10 because the L-1011 cockpit design utilized lighted pushbutton switches with color or ON/OFF illumination modes to indicate switch state in place of conventional toggle switches. These lighted pushbutton switches were generally considered to be advisory-type alerting functions whereas the toggle switches were presumed to have no alerting function. If these functions on the L-1011 were deleted from the data so as to get more equivalent sets of data, the L-1011 would have heavier reliance on warning and caution functions than the 727 or DC-10.

The increase in the number of alerting functions from the 707/DC-8 aircraft to the 747 is also evident in the four-engine aircraft data presented in figure 4. The 747 alerting system design incorporates approximately the same number of warnings, substantially more cautions, and also substantially more advisories. On a percentage distribution basis, the 747 relies the least of any four-engine commercial transport on warning functions, approximately the same as older designs on caution-type alerts and more heavily on advisory-type alerts than older four-engine transports.

From these analyses three significant factors were noted:

- Each new aircraft has incorporated more alerting functions than previous similar aircraft because of:
  - (1) Differences in the operators' alerting system utilization philosophies
  - (2) Differences in the airframers' cockpit design philosophies
  - (3) Additional regulatory requirements

- (4) Increased size of the later vintage aircraft
- (5) Use of more complex systems to save weight
- Number of warning-type alerts used in commercial turbojet transport aircraft nearly doubled in the transition from narrow body aircraft to wide body aircraft.
- Number of caution- and advisory-type alerts used in commercial turbojet transport aircraft has increased substantially with each new aircraft design.

### 2.1.3.2 Mechanical Distribution of Alerts

Trends in the type of mechanical devices used to present the alerts were analyzed by dissecting the alerting function information into the following categories:

- Distribution of the alerts between lights, aural, flags, and bands as a function of type of aircraft operation (short haul, medium range, long range), aircraft size, and aircraft vintage.
- Amount of multifunctioning of the alert devices.

From these analyses, characteristics of the alerting systems that are considered good and should be retained, or causing problems for the pilots and should be eliminated, were sought.

Figure 6 specifies the number of alerting functions to which each basic type of alerting device has been applied. Figure 7 presents the same data as a function of aircraft vintage. In the analysis of these data, it was noted that among two-engine short-haul aircraft, the 737 and DC-9 alerting systems incorporate significantly more lights and bands than the BAC-111. However, the application of aural and flags is approximately equal in these two-engine aircraft.

The difference in the number of lights incorporated in these cockpits is due primarily to the cockpit design philosophy applied to these aircraft. The design philosophy on the BAC-111 appears to have been "keep the cockpit very simple—give the pilots just enough information to fly the airplane, don't provide detailed subsystem operation information that the pilots have no control over, and don't burden them with maintenance information." In contrast to this philosophy, the DC-9 and 737 cockpits appear to have been designed to provide the crew with more detailed subsystem information (more lights and bands) so that the pilots can try to resolve malfunctions in flight and can record better maintenance data. Additionally, the DC-9 and 737 had to meet more regulatory requirements as noted earlier.

The three-engine aircraft data indicate that discrete lights were used in place of round dial instrument alert bands on the L-1011. The newer wide body three-engine aircraft also used more flags than older narrow body aircraft. This is probably due to more complex autopilot and avionics systems.

The four-engine aircraft data indicate similar trends. The increase in the number of alerting functions on the 747 over 707/DC-8 vintage aircraft occurred primarily in the number of lights used to annunciate detailed subsystem information. A slight decrease in the number of colored bands used to annunciate alerts accompanied this increased dependence on discrete alert lights.

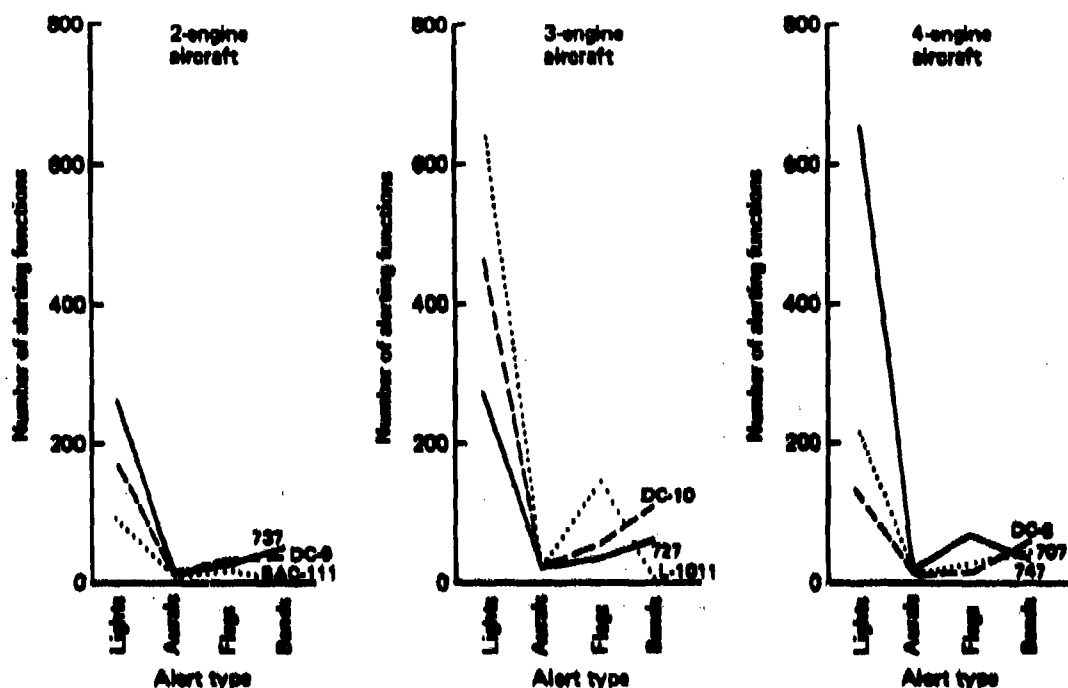


Figure 6 Mechanical Distribution of Alerting Functions

The total number of alert lights, aural, flags, and bands may have changed significantly from one aircraft to another. However, the proportionate mixture of types of alerting devices did not change significantly between aircraft. Figure 8 illustrates this situation for alert lights.

The aircraft vintage data presented in figure 7 indicate that among the narrow body aircraft no significant change in the number of alert lights, aural, flags, or bands occurred. Aircraft size, types of operation, and vintage had not effect on the design of alerting systems during this era. However, the wide body aircraft utilize substantially more alert lights and flags than narrow body aircraft. The wide body aircraft also rely slightly more on aural alerts than narrow body aircraft. The use of color bands as alert devices increased with the DC-10, decreased slightly with the 747, and decreased significantly with the L-1011. Thus, in general it can be stated that a trend currently exists toward incorporating more and more alerting devices into the cockpit.

Figures 9 and 10 illustrate the amount of multifunctioning of the alert lights on these aircraft. Multifunctioning is defined as any situation in which an alerting device is used to annunciate more than one hazardous or abnormal situation. The distinctions between the various situations annunciated by a device could be made by any obvious mode change, such as a color change, steady versus flashing or intermittent annunciation, or a change in brightness. The data in these figures indicate that a trend toward more multifunctioning exists. The BAC-111 and 727 did not utilize multifunctioning whereas the wide body aircraft used considerable multifunctioning. Increased usage of multifunction alert lights is the result of attempts to crowd more and more information into the cockpit. Available panel space became saturated and multifunction devices had to be used to get the information into the cockpit.

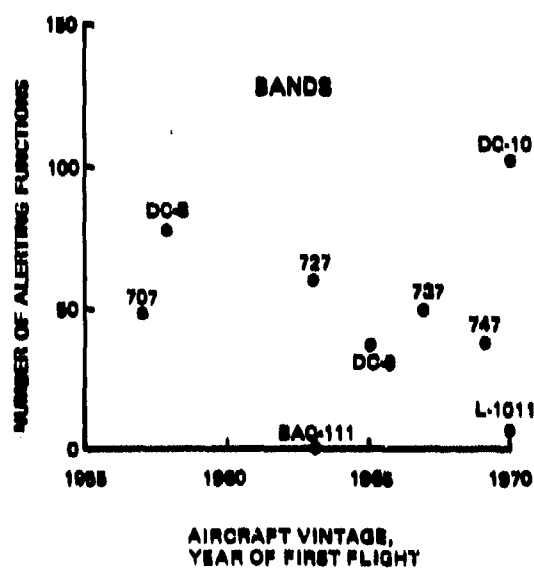
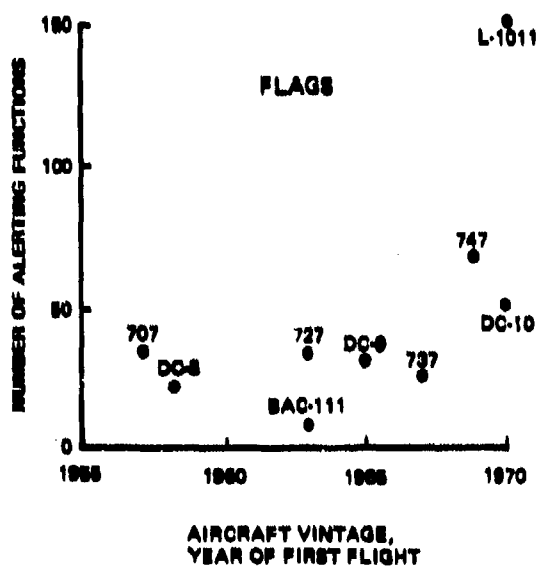
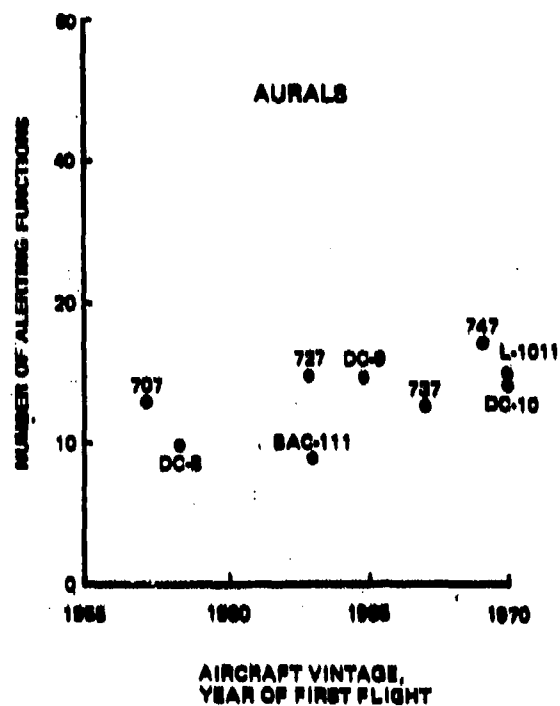
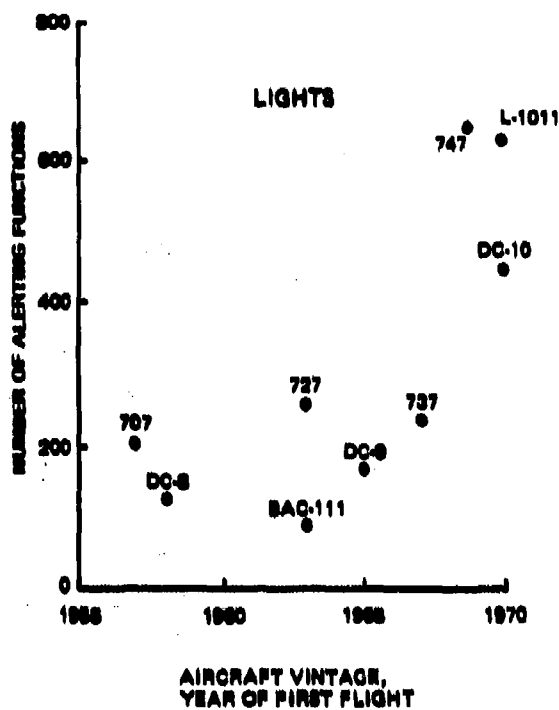
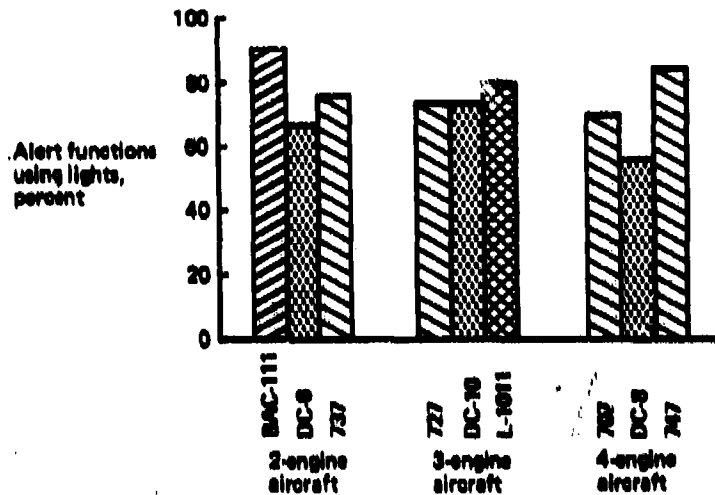


Figure 7 Application of Alerting Devices as a Function of Aircraft Vintage



**Figure 8 Proportion of Alerts That Use Lights**

Based on the results of these analyses, the alerting system utilization philosophies applied to the wide body aircraft appear to have included the following premises/suppositions:

- The crew should perform more system debug and maintenance functions; to do this, more detailed systems information needs to be displayed.
- Multifunction alert devices would not degrade the effectiveness of the alerting systems.
- Discrete alert lights are more effective than analog displays (dial type instruments).
- A slight increase in the large number of already existing aural alerts would not degrade the effectiveness of the alerting system.
- The narrow body aircraft cockpit designs did not saturate the crew. A typical crew can handle substantially more complex situations than exists on narrow body aircraft.

The validity of these premises will be discussed in further detail in later sections.

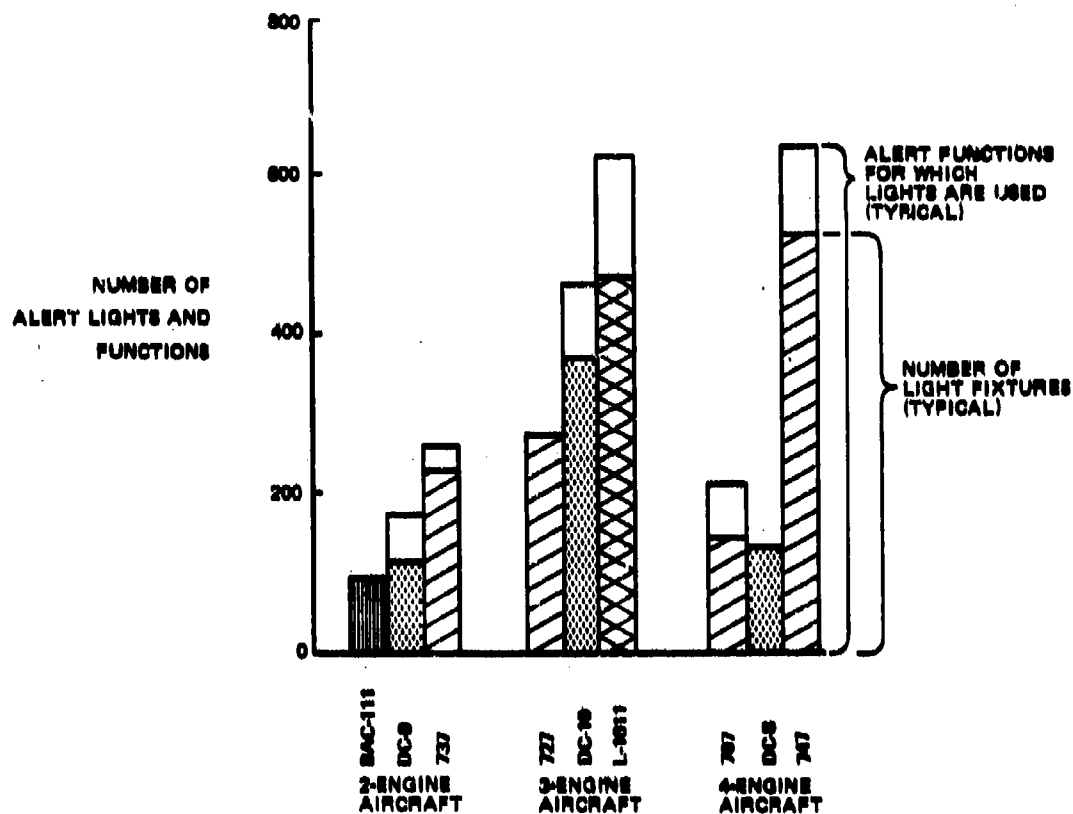


Figure 9 Number of Alerts Using Lights on Each Basic Aircraft Type

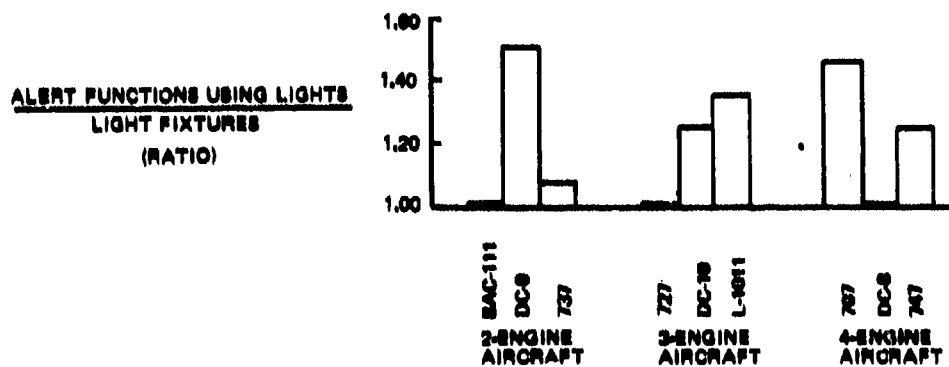


Figure 10 Amount of Multifunctioning of Alert Lights



### 2.1.3.3 Color Distribution of Visual Alerts

Red, fire orange, and dayglow orange colored alerts are generally used to present warnings; amber and yellow colored alerts are used to present caution; and blue, green, or white colored alerts are used to present advisories and status indications. More specifically, blue alerts usually indicate that something is in transit, green alerts usually indicate that a system is operating satisfactorily and/or has attained a SAFE/GO status; and white alerts usually indicate a system is ON. The distribution of alerts among these colors was analyzed to determine whether a trend toward presenting any particular type of information exists. To perform these analyses, the alerting functions data was again dissected into the type of aircraft operation, size of aircraft, and vintage of the aircraft.

These data are presented in graphical form in figures 11 through 14 and in tabular form in appendix B (table B-3).

The data in figure 11 indicate the following significant factors:

- Essentially no difference between aircraft in the application of red lights
- L-1011 and 747 aircraft rely on amber/yellow lights more heavily than other aircraft
- BAC-111 utilizes very few blue lights
- 737, 747, and DC-10 aircraft rely more heavily on green annunciators than all other aircraft
- L-1011 aircraft use white lights extensively (to replace conventional toggle switch functions)

The data in figure 12 indicate that the wide body aircraft use significantly more red flags than narrow body aircraft and the 707 uses substantially more white flags than other aircraft. The heavy reliance on red flags in the wide body aircraft is due to incorporation of more complex autopilot and navigation systems. The 707 occasionally used white flags where other aircraft generally used red or amber lights.

The data on the application of color bands as alerting devices (figure 13) indicate that the DC-10 utilizes substantially more amber/yellow bands than other aircraft, the L-1011 does not utilize green bands, and L-1011 and BAC-111 aircraft utilize very few bands.

Analyses of the historical application of alert colors (figure 14) revealed significant trends toward more amber/yellow and white lights, more red flags, and fewer red and green bands. The increase in amber lights is due to requirements for more detailed subsystems information in the cockpit. More red flags are being incorporated because of more complex autopilot and navigation systems in the newer aircraft. The traditional red and green bands are being replaced by amber lights.

The following conclusions were derived from these analyses:

- The number of warnings has increased slightly because of red flags that are required to annunciate the new failure modes of more complex autopilots and navigation systems

- Amber and yellow lights are being used more extensively with each new generation of aircraft to annunciate detailed subsystem operations
- A trend toward annunciating more SAFE and GO conditions with green lights exists
- White lighted pushbuttons are being used more extensively in place of toggle switches in each new generation of aircraft.
- Discrete alert lights are being used to replace traditional color bands

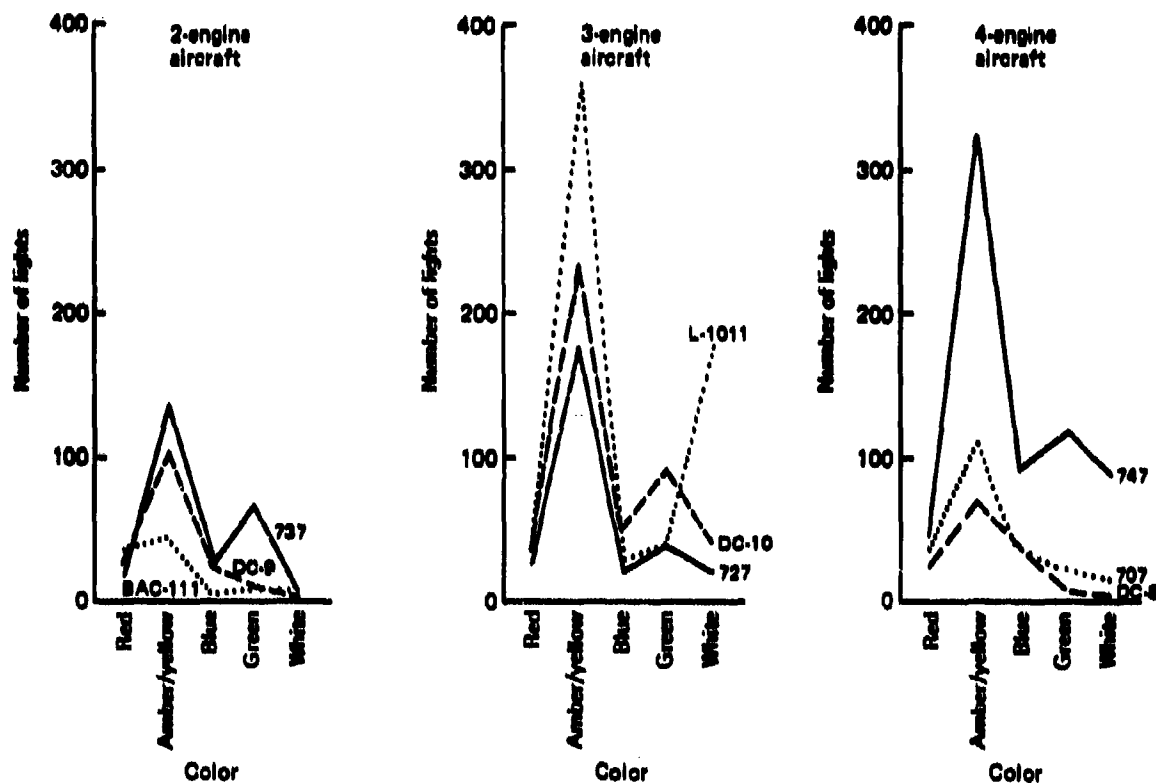


Figure 11 Color Distribution of Lights

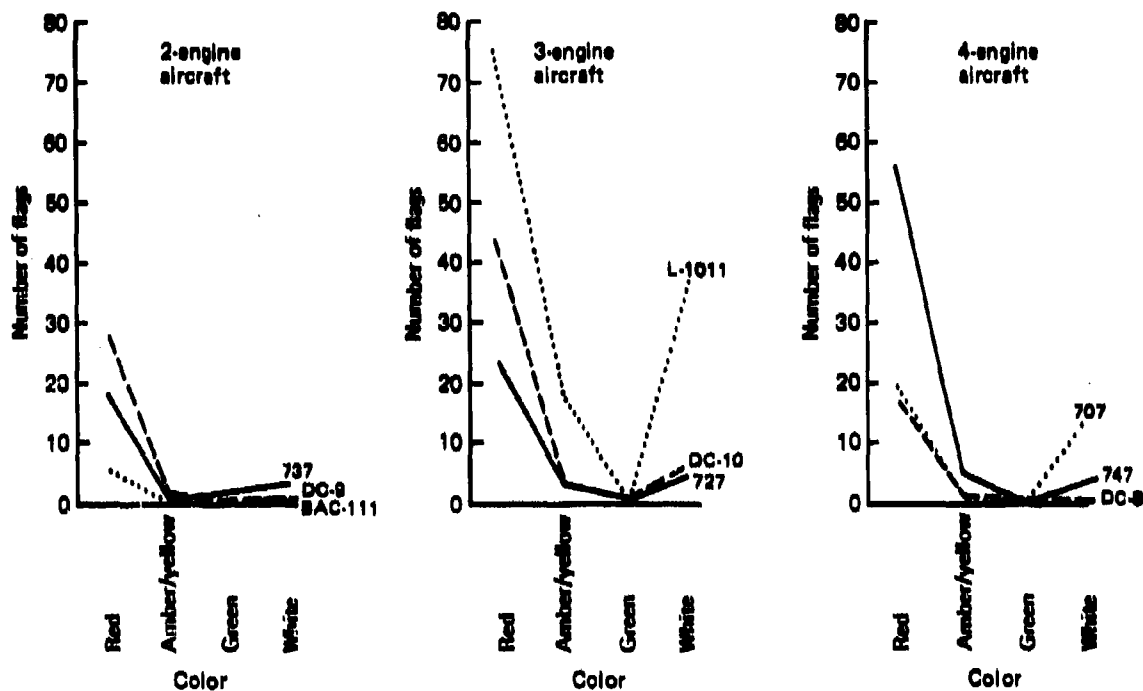


Figure 12 Color Distribution of Flags

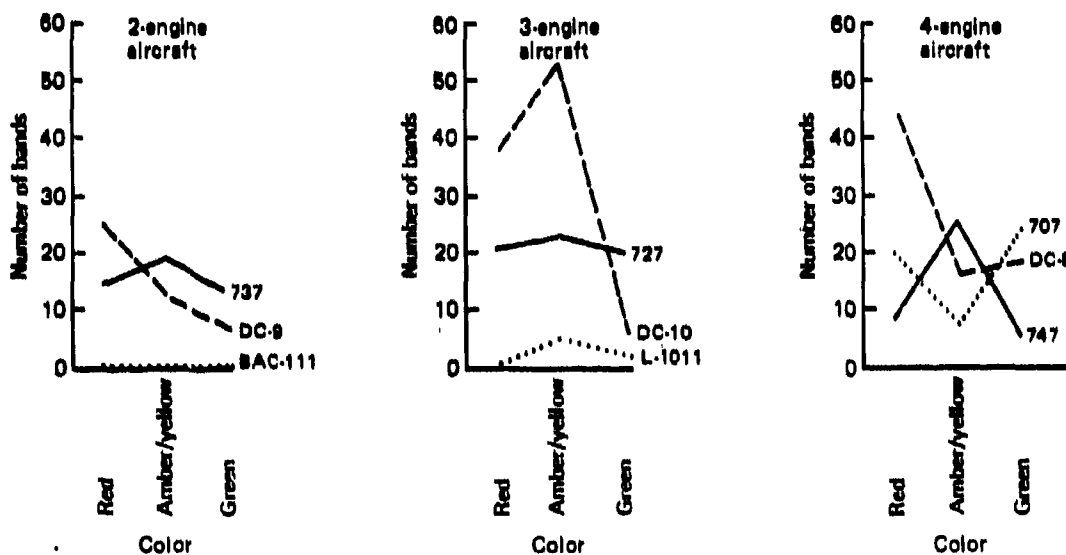


Figure 13 Color Distribution of Bands

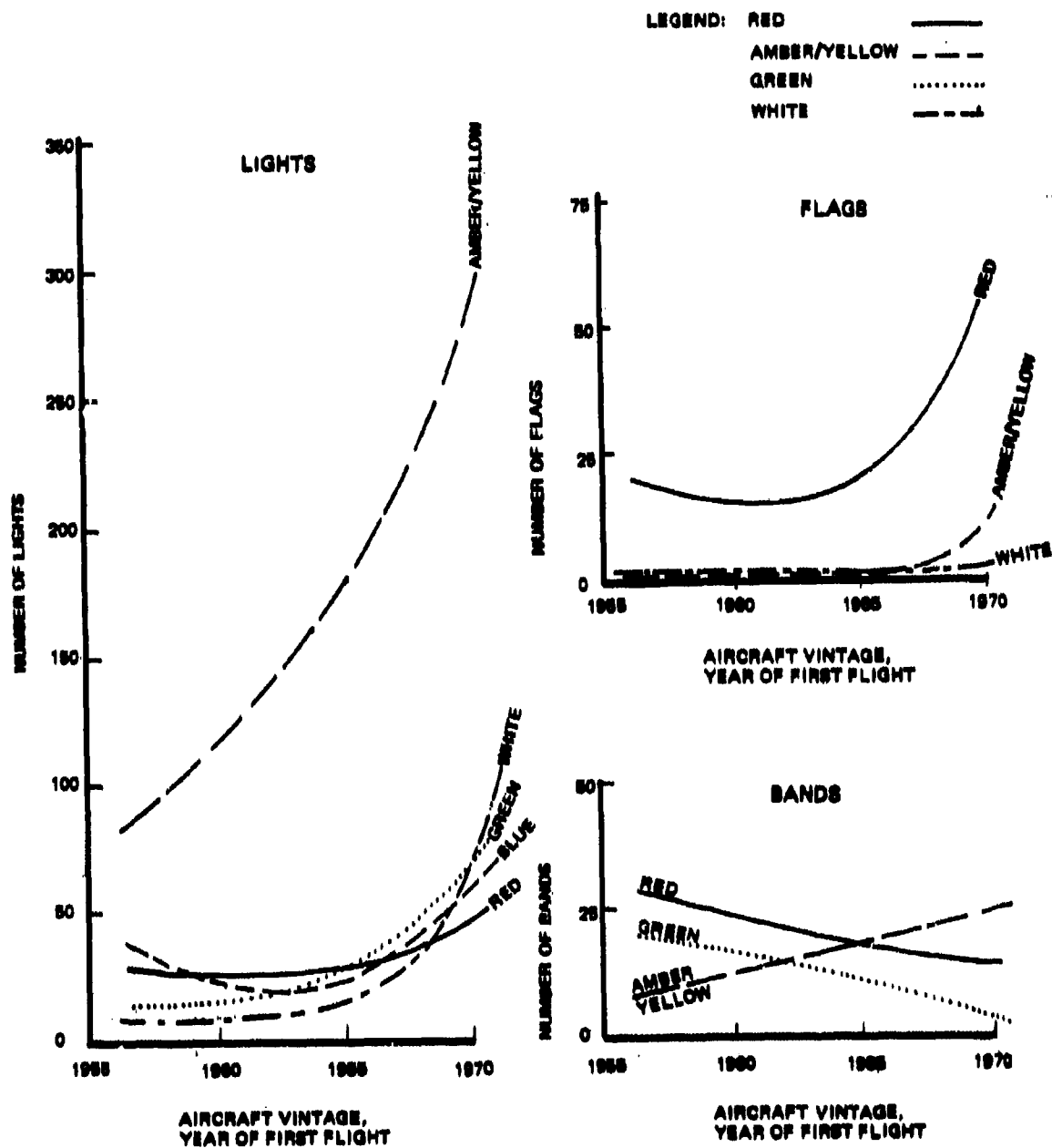


Figure 14 Application of Alert Colors as a Function of Aircraft Vintage

#### 2.1.3.4 Aural Alert Applications

Table 5 provides a listing of the various situations for which aural alerts are used. For each situation listed, the type of aural alert used on each aircraft type is specified. Where it could be determined that no aural alert is provided for the situation, "none" is entered; if it could not be determined, the space is blank.

From this table, it is noted that all aircraft considered in this study use a bell to annunciate an engine fire. However, the characteristics of the bell vary from one aircraft to another. Similar situations exist among all the other aural alerts. Thus, another listing (table 6) that describes the frequency, loudness, and continuity characteristics of each specified aural alert is provided.

The cockpit ambient noise environment in which these aural alerts must function is specified, as a point of reference, in table 7. The ambient noise levels specified in this table represent the maximum average octave band value within the specified frequency ranges. These values were taken from the cockpit noise curves provided in appendix C.

Examination of these data for (1) consistency of application, (2) factors that may contribute to confusion in the cockpit and should be avoided in the design of future alerting systems, and (3) aural alerts that have been standardized on and should be retained, revealed the following facts:

- No consistent utilization philosophy has been applied to the aural alerts, not even within any airframer's or operator's aircraft.
- The number of aural alerts is increasing. Older narrow body aircraft incorporated 9 to 15 aural alerts and newer wide body aircraft have 14 to 17 aural alerts. Human factors data indicate that pilots can rapidly and accurately interpret only a limited number of discrete aural alerts and that this number decreases as a function of time since recurrent training. The exact number of alerts that the average pilot can effectively recognize is not known. However, the potential for confusion is known to exist currently and should be eliminated.
- A standard appears to have been established for the following aural alerts:

<u>Alert Situations</u>	<u>Type of Aural Alert</u>
Engine fire	Bell
Excessive airspeed	Clacker
Unsafe landing condition	Horn
Unsafe takeoff condition	Horn
Ground proximity	Warbler and voice message or tone and voice message

The specific characteristics of the aural alerts used for each of these situations varies slightly but the basic function appears to be identical in all cases.

Table 5 Summary of Currently Used Cockpit Aural Alerts

Type of aural alert applied		707/727	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
Alert condition	Airplane	707/727	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
Altitude alert		"C" chord A	Tone A, B "C" chord A	"C" chord A	"C" chord A	Horn	Horn**	"C" chord B	"C" chord B	•
APU fire		None	Bell A	Bell A	Bell A	None	None	None	Bell E	Bell
Attitude displays disagree		None	None	None	Tone B	None	None	Wailer (provisional)	None	•
Autopilot disengage		None	Wailer A (some acft)	None	Wailer A	None	Click	Wailer B	Wailer C	•
Call on interphone		Chime G	Chime G	Chime G	None	Chime	Chime	Chime	Chime N	•
Close proximity to ground, gear up		Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice
Cockpit call from flight attendants		Chime	Chime	Chime	Chime	Chime B Chime C	Chime B Chime C	Chime B Chime C	Chime H	•
Cockpit call from ground crew		None	None	None	Chime E	Chime	Chime	Chime	Chime P	•
Cockpit call to flight attendants		Chime	Chime	Chime	Chime D Chime L	Chime	Chime	Chime	Chime M	•
Decision height		Tone C	Tone C	Tone C	"C" chord A	None	Tone	None	Tone H	•
500-foot terrain warning		None	Tone	None	Tone	None	Tone	None	Tone	•
Emergency evacuation		Tone B	Tone B	None	Chime F Tone B	None	Horn	Horn	Tone F	•
Engine fire		Bell A	Bell A	Bell A	Bell A	Bell B	Bell B	Bell C	Bell E	Bell
Excessive airspeed		Bell D	Clacker A	Clacker A	Clacker A	Clacker D	Clacker D	Clacker C	Clacker F	Bell
Excessive sink rate		Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice

\* Characteristics unknown

\*\* Not delivered but available

Table 5 Summary of Currently Used Cockpit Aural Alerts (Cont)

Type of aural alert applied										
Alert condition		707/727	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
Airplane										
Excessive terrain closure rate		Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice
Flap load relieve inoperative		None	None	None	None	None	None	None	Buzzer B	•
Galley overheat		None	None	None	None	None	None	None	Tone E	•
Inadvertent "duck under" GS		Voice	Voice	Voice	Voice	Voice	Voice	Voice	Voice	Voice
Low cabin pressure		Horn E	Horn E	Horn E	Horn F	Horn L	Horn L	Horn: H	Horn S	•
Negative climb after takeoff		Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice	Warbler & voice
SELCAL		Chime J	Chime J Chime H	Chime H	Chime K	Chime	Chime	Bell	Chime M	•
Instrument comparator alert		Clacker B	Clacker B	Clacker B	None	None	None	None	None	•
Smoke in cargo area		Bell A	None	Bell A	Bell A	None	None	None	None	•
Smoke in lower galley		None	None	None	None	None	None	None	Tone E	•
Stabilizer in motion		Clacker	Clacker	Clacker	Clacker	Horn J (on .60 models)	Horn K	Horn G	None	•
Unsafe ground condition		None	Horn A	None	None	None	None	None	None	•
Unsafe in-flight condition		None	Horn E	None	None	None	None	None	None	•
Unsafe landing condition		Horn A	Horn A	Horn A	Horn B	Horn C	Horn C	Horn D	Horn R	•
Unsafe takeoff condition		Horn E	Horn E	Horn E	Horn F	Horn L	Horn L	Horn H	Horn S	Horn S
Wheelwell overheat or fire		Bell A	Bell A	Bell A	Bell A	None	None	None	Bell E	•

\*Characteristics unknown

Table 6 Aural Alert Characteristics

AURAL ALERT	FREQUENCY, Hz	LOUDNESS, dB	DESCRIPTION
HORN A	200 TO 443	90 $\pm$ 5	Continuous
HORN B	220 TO 280	93 $\pm$ 5	Continuous
HORN C	835	89	Continuous
HORN D	802 AND 857	85 $\pm$ 5	Continuous
HORN E	200 TO 443	90 $\pm$ 5	Same as horn A, except interrupted
HORN F	220 TO 280	93 $\pm$ 5	Same as horn B, except interrupted at 3 Hz
HORN G	116 AND 259		Continuous
HORN H	802 AND 857		Same as horn D, except interrupted at 1 Hz
HORN J	140	91	On 0.5 seconds; off 0.5 seconds in variable-sized groups; 2 seconds between groups
HORN K	60	85	On for 0.5 seconds; off for 1 second
HORN L	635	84 TO 98	Interrupted at 0.6 Hz
HORN M	825	95	Interrupted at 0.6 Hz
HORN N	325 AND 390	94	Two tones alternating at 0.25 Hz
HORN P			"Ooga" horn
HORN R	300	85	Continuous
HORN S	300	90	333-ms period with a 50% duty cycle
TONE A	1000		Continuous
TONE B	2800 $\pm$ 300	90 $\pm$ 5	Beeper tone, pulsating at 1.5 to 5.0 Hz
TONE C	800	INCREASING	Tone that increases in volume over a 3-second period
TONE D	400	INCREASING	New system for McDonnell Douglas airplanes, application uncertain
TONE E	1.4 k TO 2.0 K	90	Alternating tone
TONE F	3 k	77	333-ms period with a 50% duty cycle
TONE G	700 TO 1.7 k	90	Pulsating tone
TONE H	1.0 K		Pulsating tone
"C" CHORD A	461 TO 563 567 TO 704 691 TO 845	95 $\pm$ 5	Intermittent
"C" CHORD B	512, 640, 768	90	Sound duration 2 seconds
BUZZER A	300, 600, AND 900	90 $\pm$ 5	
BUZZER B	90	81	2 seconds
WARBLER & VOICE	400 TO 800	85 TO 98	Three "whoops" per second; followed by voice saying "pull up." Some of the airplanes indicated do not have this system and some have the warbler without voice
WAILER A	130 $\pm$ 20 TO 200 $\pm$ 30	93 $\pm$ 3	2 to 4 Hz of variation between longer and higher frequencies—minimum variation 49 Hz—mod 4.76 Hz
WAILER B	640		
WAILER C	130 TO 200	88	
BELL A	600 TO 10,000	93 $\pm$ 5	Continuous
BELL B	750	87	Continuous; striker frequency, 1.8 Hz similar to telephone
BELL C	640 AND 648		Continuous; two tones alternating, striker frequency, 12.5 Hz
BELL D	600 TO 10,000	95 $\pm$ 5	Same as bell A, except interrupted



Table 6 Aural Alert Characteristics (Cont)

AURAL ALERT	FREQUENCY, Hz	LOUDNESS, dB	DESCRIPTION
BELL E	100		"Gong" type bell—electrically activated
CLACKER A	1000 TO 2400	86	Modulated at 5 to 10 Hz
CLACKER B			Repetition frequency, 1 Hz
CLACKER C	512		Repetition frequency, 4.76 Hz, sounds like clucking of a chicken
CLACKER D	TWO TONES, CLICKS	84 TO 96	Repetition frequency, 9 Hz
CLACKER E	336	87	Similar to a square wave, modulated with very distinctive clicks at 10 Hz
CLACKER F	2500	86	Two bursts in a 20-ms interval repeated at a 140-ms rate
CHIME A	820	87	Repeating, 1.5 second repetition rate
CHIME B	750	76 TO 84	Single stroke gong-like sound; when mechanics call, interrupted at 0.85 Hz
CHIME C	4700	76	Single stroke gong-like sound
CHIME D	727 TO 947	$95 \pm 5$	"High chime", single stroke gong-like sound
CHIME E	477 TO 497	$95 \pm 5$	"Low chime", single stroke gong-like sound
CHIME F	727 TO 947 AND 477 TO 497	$95 \pm 5$	High-low chime combination of chimes; D and E repeated at a rate of $3 \pm 1$ Hz
CHIME G	588	$95 \pm 5$	"High chime", single stroke gong-like sound
CHIME H	588 AND 408	$95 \pm 5$	High-low chime not repeated
CHIME J	588 AND 488	$95 \pm 5$	Same as chime H except fast repeat
CHIME K	588 AND 488	$95 \pm 5$	Same as chime H except it does two cycles and stops
CHIME L	727 TO 947 AND 477 TO 497	$95 \pm 5$	Same as chime F except it does two cycles and stops
CHIME M	587	85	Single chime in most configurations
CHIME N	587/487	85	Single high/low chime
CHIME P	487	85	Low chime not repeated
CLICK			Actual sound of disconnect of the autopilot lever

**Table 7 Cockpit Ambient Noise Environment**

AIRCRAFT	FREQUENCY RANGE, Hz FLIGHT PHASE	AMBIENT NOISE LEVEL, dB*			
		0-200	200-1000	1000-4000	4000-10,000
707-720	TAKEOFF	99	93	79	73
	FINAL APPROACH	90	81	75	72
727	TAKEOFF	88	79	68	61
	FINAL APPROACH	87	73	66	61
737	TAKEOFF	88	84	70	66
	FINAL APPROACH	84	82	78	75
747	TAKEOFF	100	83	77	70
	FINAL APPROACH	90	81	76	71
DC-8	TAKEOFF	96	95	79	73
	FINAL APPROACH	85	81	71	67
DC-9	TAKEOFF	84	77	68	61
	FINAL APPROACH	85	72	69	66
DC-10	TAKEOFF	91	91	78	70
	FINAL APPROACH	82	75	67	66
L-1011	TAKEOFF	84	76	75	68
	FINAL APPROACH	84	72	70	63

\*VALUES LISTED ARE THE MAXIMUM LEVELS TO OCCUR WITHIN THE SPECIFIED FREQUENCY RANGES

### 2.1.3.5 Color of Visual Alerts Associated With Aural Alerts

The number of aural alerts has increased to the point where the potential for confusion exists. To avoid confusion over the significance of an aural alert, cockpit designers have augmented them with identification lights. Figure 15 illustrates the type of visual alerts that are activated when aural alerts occur. These data indicate that the best correlation between the aural alerts and red visual alerts exists on the 737. It is generally assumed that aural alerts are used for high priority annunciations and incoming communication alerts. However, these data show that a significant number of amber and yellow alerts indicating caution conditions also are associated with the aural alerts. The blue lights are associated primarily with incoming communication alerts.

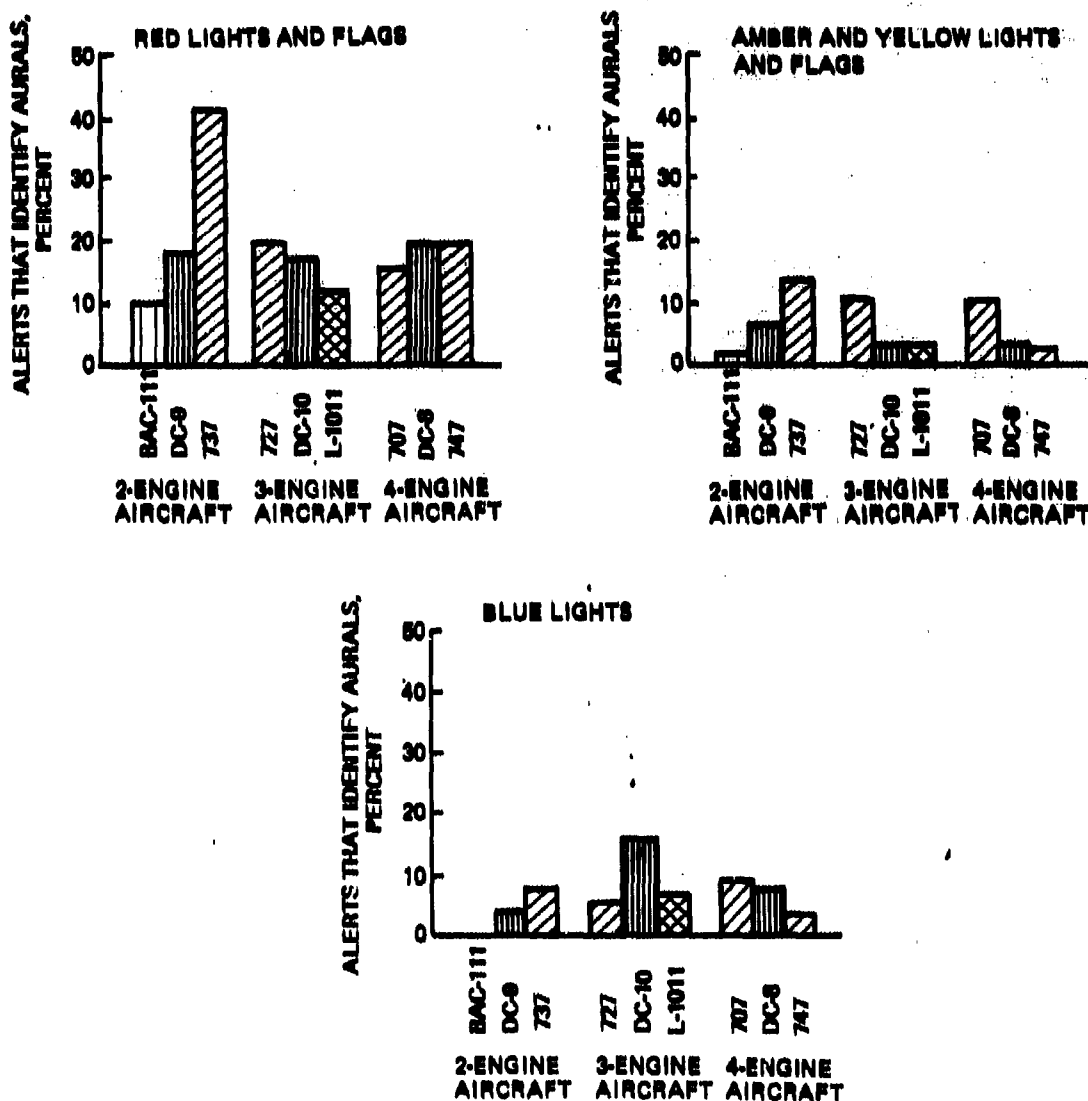


Figure 15 Percent of Lights and Flags Associated With Aural Alerts

Figure 16 specifies the color distribution of visual alerts associated with the aural alerts. The heavy reliance of Boeing 707, 727, and 737 aircraft on amber lights that identify aural alerts is reflected in these data. These data also indicate that DC-8 and DC-10 aircraft utilize significantly blue lights than all other aircraft to help identify aural alerts.

The historical correlation between the growth in aural alerts and the total number of lights and flags to help identify the aural alerts was analyzed from the data presented in figure 17. These data indicate that all aircraft, except the BAC-111, have multiple lights and flags associated with each aural alert; 727, 737, and DC-10 aircraft have significantly more visual backup lights for each aural alert than similar type aircraft; the BAC-111 relies least of all aircraft on visual backup lights; and the wide body jets rely less than narrow body aircraft on visual backup lights even though they have more aural alerts. All aircraft also were noted to have several aural alerts that operate without visual backup alerts as indicated in table 8.

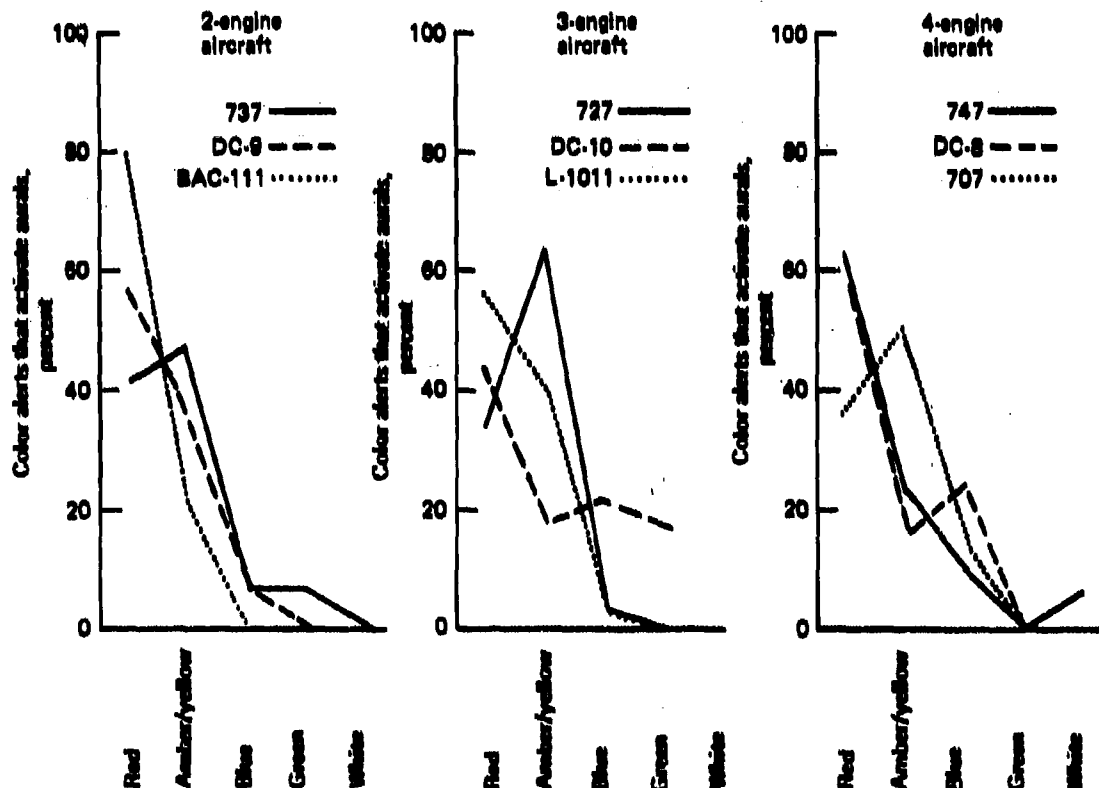
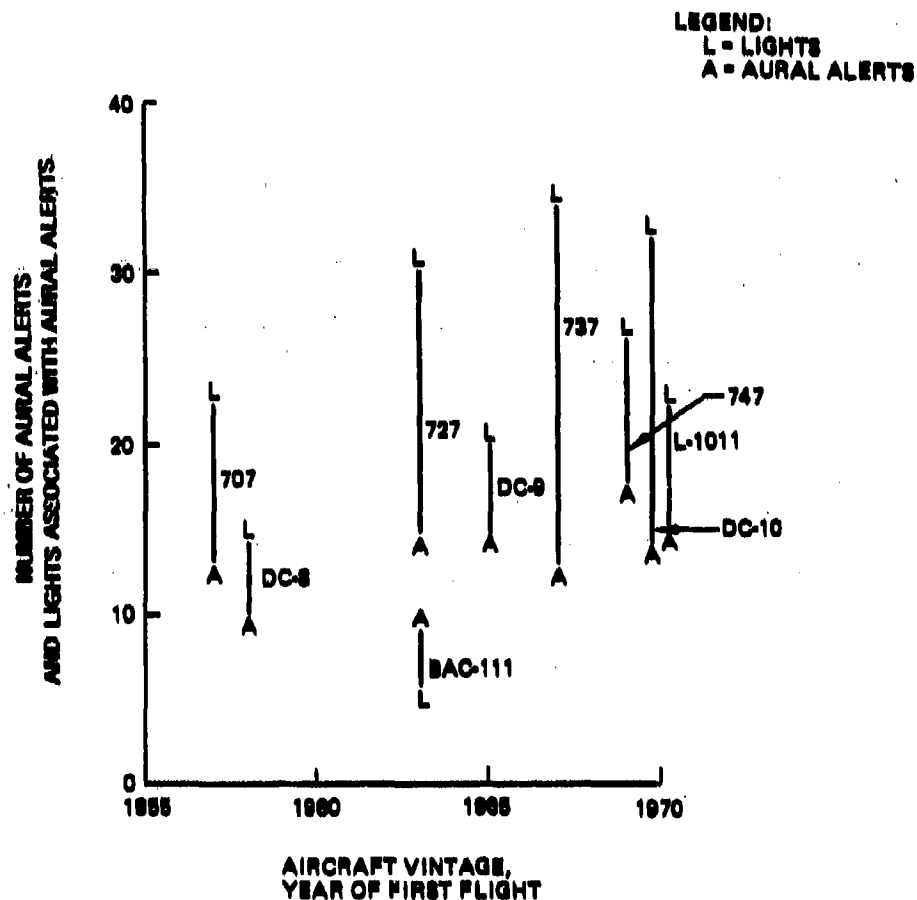


Figure 16 Color Distribution of Visual Alerts That Activate Aural



*Figure 17 Historical Application of Aural Alerts and Identification Lights Supporting Aural Alerts*

*Table 8 Application of Aural Alerts Without Visual Backup Lights*

Aircraft type	Number aural without visual backup lights
707	5
727	6
737	3
747	6
DC-8	4
DC-9	3
DC-10	3
L-1011	4
BAC-111	6

### 2.1.3.6 Aircraft Systems Causing Proliferation of Alerts

Tables D-1 through D-9 in appendix D specify the distribution of alerts used by each subsystem on each basic type of airplane. These data are summarized in figure 18 in a form that illustrates which subsystems are causing increases in the number of alerts. Caution must be used in interpreting the data curves presented in this figure because (1) not all systems incorporated in the newer model aircraft were incorporated in the older model aircraft, e.g., autoland systems; (2) the aircraft developed in the mid-1960s were the midsize and smaller narrow body aircraft as opposed to the larger narrow body aircraft that constitute the data points at the start of the curve and the large wide body aircraft that constitute the data points at the end of the curve. Therefore, if all aircraft were equal, the left end of some curves would be lower than the right end and/or some curves would dip in the middle. A third factor that influences these data is the trades made between presenting systems information via alert lights as opposed to dial-type indicators. For example, on most Boeing aircraft, the air-conditioning and electrical systems require approximately an equal number of functions presented to the pilot. Most of these functions could be presented by either lights or dial-type indicators. However, the electrical systems have transitioned to lights and the air-conditioning systems have retained dial-type indicators without alert bands as the primary method of presenting information. Operating limits are generally downgraded, deemed less critical, if dial-type indicators are used. Thus electrical systems would be more likely to show a proliferation of alerts than air-conditioning systems. Cognizance of all these factors and the magnitude of influence of these factors is required when interpreting these data.

Examination of these data reveals that the most rapid growth in the number of subsystem alerts has occurred in the following systems:

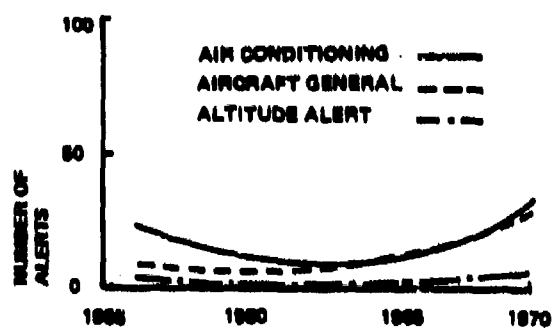
- Electrical
- Automatic flight control system (AFCS)

Secondary offenders are the following systems:

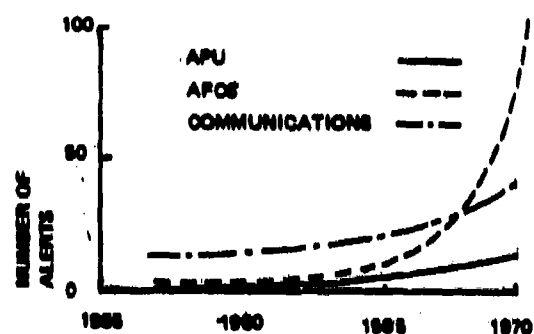
- Hydraulics
- Ice and rain protection
- Landing gear and brakes
- Navigation
- Pneumatics

Subsystems in which negligible growth in the number of alerts has occurred are the following:

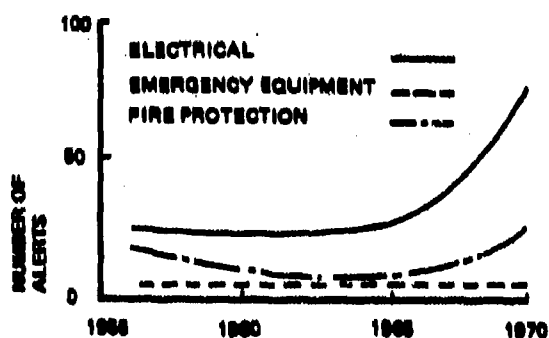
- Air-conditioning
- Altitude alert
- APU



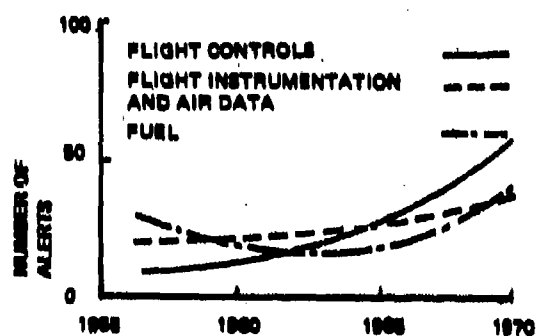
AIRCRAFT VINTAGE,  
YEAR OF FIRST FLIGHT



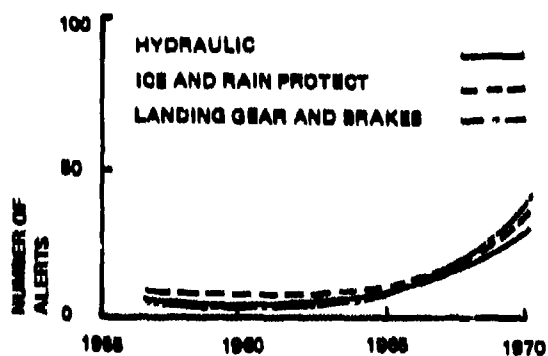
AIRCRAFT VINTAGE,  
YEAR OF FIRST FLIGHT



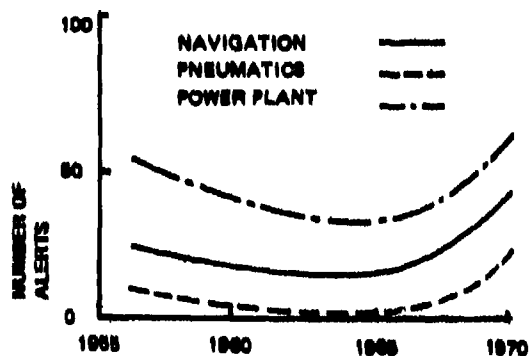
AIRCRAFT VINTAGE,  
YEAR OF FIRST FLIGHT



AIRCRAFT VINTAGE,  
YEAR OF FIRST FLIGHT



AIRCRAFT VINTAGE,  
YEAR OF FIRST FLIGHT



AIRCRAFT VINTAGE,  
YEAR OF FIRST FLIGHT

Figure 18 Growth History of Subsystem Alerts

- Communications
- Emergency equipment
- Flight instruments and air data
- Fuel
- Powerplant

Inspection of the detailed data in appendix D indicates that most of this growth is occurring among the caution and advisory lights.

#### 2.1.3.7 Applications of Master Caution/Master Warning Systems

Table 9 specifies the aircraft that utilize master caution and master warning systems, the location and number of lights provided for these functions, and the characteristics of associated aural alerts. Table 10 specifies the proportions of lights that will actuate either the master caution or the master warning.

Analyses of these data indicated that master caution and/or master warning systems are used in all two-man-crew aircraft but in only a few three-man-crew aircraft. The majority of the three-man-crew aircraft use a central block of lights to annunciate caution and warning situations. The 737, DC-9, and DC-10 aircraft use a combination of the central block of annunciation lights and master caution/master warning.

The type of secondary alerts that actuate the master warning alert(s) also varies considerably from aircraft to aircraft. For example, on the DC-10 nearly two-thirds of the red lights actuate the master warning signal whereas on the DC-9 only one-third of the red lights activate the master warning. No amber, blue, green, white, or clear lights on these aircraft, except the BAC-111, activate the master warning signal.

Two amber lights on the BAC-111 activate the master warning. The rationale behind this discrepancy may be that the situation (CSD failure) deserves special attention and, since no master caution exists in this aircraft, the master warning signal was utilized.

The DC-9 and DC-10 alerting systems are designed to augment recognition of the cabin pressurization aural alert with the master warning. No other aural alerts activate the master warning systems. No inconsistencies appeared in the master caution system implementations. The master caution systems in these aircraft activate only when an amber light on the overhead panel or flight engineer's station illuminates.

#### 2.1.3.8 Applications of Alert Prioritization and Inhibits

Figures 19 and 20 indicate respectively (1) the aircraft that have alerting systems with prioritized aural alerts and (2) the aural alert prioritization scheme incorporated on recent production models of the 737. No aircraft except late model 737s and a few 727s have an aural alert prioritization system. The priority scheme implemented on these 737s allows the aural alerts for FIRE and OVER-



**Table 9 Master Caution and Master Warning Applications**


ALERT TYPE	AIRCRAFT TYPE	VISUAL ALERT		AURAL ALERT
		LOCATION	QUANTITY	
MASTER WARNING	BAC-111	PILOTS MAIN PANEL	2	
	DC-8	GLARESHIELD	1	
	DC-9	GLARESHIELD	2	
	DC-10	GLARESHIELD AND FLIGHT ENGINEER'S STATION	2+1 RESPECTIVELY	
MASTER CAUTION	737	GLARESHIELD	2	
	DC-9	GLARESHIELD	2	
	DC-10	GLARESHIELD AND FLIGHT ENGINEER'S STATION	2+1 RESPECTIVELY	
CENTRAL WARNING AND CAUTION BLOCK OF ANNUNCIATIONS	737	GLARESHIELD	2	
	747	PILOTS ENGINE INSTRUMENT PANEL AND FLIGHT ENGINEER'S STATION	1+1 RESPECTIVELY	
	DC-9	OVERHEAD	1	
	DC-10	OVERHEAD AND FLIGHT ENGINEER'S STATION	1+1 RESPECTIVELY	
	L-1011	PILOTS ENGINE INSTRUMENT PANEL AND FLIGHT ENGINEER'S STATION	1+1 RESPECTIVELY	

Table 10 Number of Alerts that Also Activate Master Caution and Master Warning Alerts

ALERT TYPE	PERCENT OF ALERTS THAT ACTIVATE MASTER WARNING				PERCENT OF ALERTS THAT ACTIVATE MASTER CAUTION		
	AIRCRAFT TYPE				AIRCRAFT TYPE		
	DC-8	DC-9	DC-10	BAC-111	737	DC-9	DC-10
RED LIGHTS	41	32	62	42	0	0	0
AMBER/YELLOW LIGHTS	0	0	0	5	54	66	20
BLUE LIGHTS	0	0	0	0	0	0	0
GREEN LIGHTS	0	0	0	0	0	0	0
WHITE/CLEAR LIGHTS	0	0	0	0	0	0	0
AURAL ALERTS	0	7*	7*	0	0	0	0

\*CABIN PRESSURIZATION

PRIORITY	ARINC 577	AIRCRAFT TYPE						
		707/720	727	737	747	DC-8	DC-9	DC-10
1	-CAS	NO PRIORI- TIZATION	NO PRIORI- TIZATION ON MOST AIRCRAFT	SEE FIGURE 20	NO PRIORI- TIZATION	NO PRIORI- TIZATION	NO PRIORI- TIZATION	NO PRIORI- TIZATION
2	-GRD PROX -ENG FIRE -APE FIRE -STALL -OVERSPEED -LDG GEAR -TAKEOFF -CONFIG -AUTO PILOT -DISCONNECT -ALTITUDE -ALERT* -SPARE -SPARE -STAB IN -MOTION -FLAP LOAD -RELIEF -SPARE -SPARE -CABIN ALT -SPARE -GALLEY -SMOKE -EMER -EVAC -SPARE -SELCAL -CABIN CALL -GRD CALL -SPARE -SPARE							
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

\* PART OF A SEPARATE ALERTING SYSTEM THAT CAN BE ACTIVATED AT ANY TIME.

Figure 19 Prioritization of Aural Alerts

SPEED to occur simultaneously; causes the aural alert for CABIN ALTITUDE and UNSAFE TAKEOFF CONFIGURATION to override any alert listed below it and the aural alert for UNSAFE LANDING GEAR to override any alert listed below it, etc.; and causes the aural alert for SELCAL to override the aural alert for CREW CALL. The aural alerts for FIRE, OVERSPEED, one item from the middle groups, and one item from the right group can occur simultaneously in this priority scheme.

In ARINC 577 a priority scheme for all aural alerting functions, currently used and anticipatable in the near future, was proposed. Three problems are immediately noted with this scheme: (1) too many aural alerts are allowed, (2) too many alerting functions have equal priority on the priority 1 level, and (3) the significance and urgency of an alert are somewhat aircraft design dependent and therefore will vary from aircraft to aircraft. The standard for prioritizing the aural alerts should provide:

- Criteria for determining whether alert prioritization is necessary
- Criteria for determining the priority level of each alert if prioritization is required
- Design guidelines for equipment that allows aircraft dependent priority assignment of the alerts

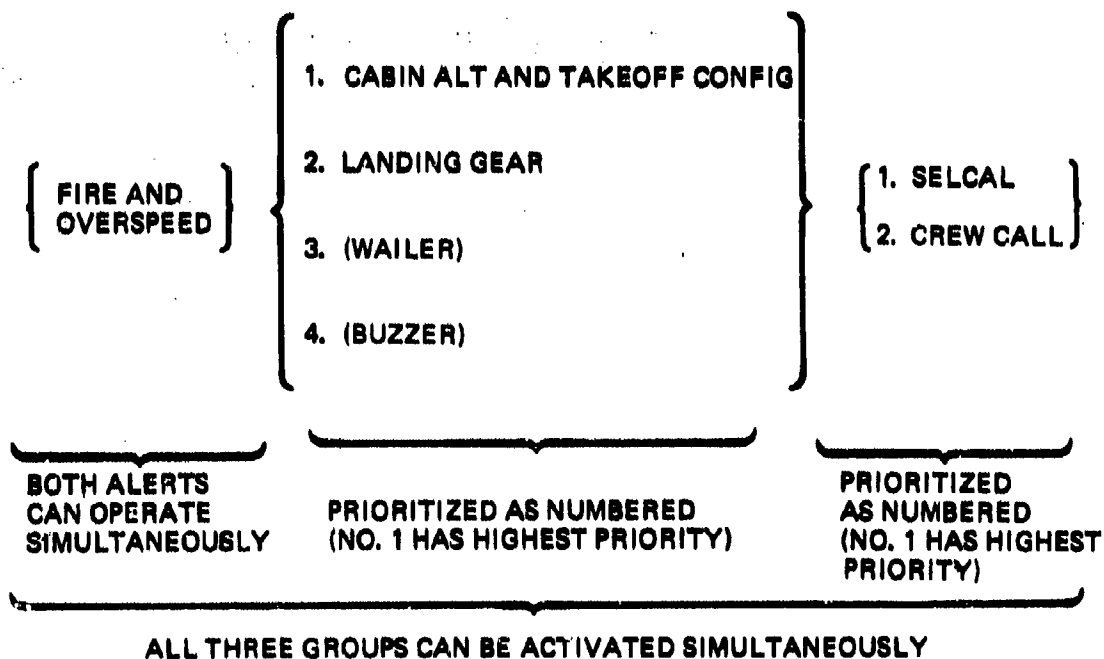


Figure 20 737 Aural Alert Priority Scheme

Alert inhibits also have not been applied extensively. The application of alert inhibits has been restricted primarily to enabling and/or disabling the aural alerts associated with aircraft configuration management, e.g., flaps extended and throttles at idle but no landing gear extended.

Not all alert inhibits are intentional, i.e., some inhibits result because the system with which they are associated or a sensor that feeds this system has exceeded its region of valid operation. An example of this situation is the ground proximity warning. Above 2500 or 5000 feet radio altitude, depending on type of equipment used, the ground proximity alert is inhibited because the radio altitude signal is not valid.

The DC-10 is the only aircraft that incorporates intentional inhibits of selected subsystem fault alerts, as described in figure 21, in addition to the traditional configuration-related alert inhibits. The inhibits on the DC-10 are designed to eliminate potential disturbances to the pilot during the critical segment of the landing maneuver, i.e., below 100 feet.

## 2.2 ALERTING FUNCTION AND SYSTEM REQUIREMENTS

In section 2.1, the good and bad features of existing alerting systems were discerned. Alerting function and system requirements were implied therefrom. In this section, a survey of applicable standards, accident data, operations and maintenance data, and pilot opinion data are discussed. An analysis of the correlation between the checklists and the alerts applied to each situation is also discussed. Additional alerting system requirements were derived from these analyses. These requirements are combined in later sections to derive "preliminary" alerting system implementation concepts. "Preliminary" is emphasized because these concepts need further human factors and operational testing to validate their effectiveness.

### 2.2.1 APPLICABLE STANDARDS

Federal Aviation Regulations pertinent to this study are parts 21, 25, 37, 91, and 121. Commercial aircraft standards applicable to this study are ARINC 577, which was discussed in section 2.1.3.8; SAE documents ARP 450, ARP 571, ARP 1068, and ARP 1161; and RTCA document D0-161A. Pertinent military standards and specifications are MIL-STD-411, MIL-STD-1472, and MIL-C-81774.

AIRPLANE	INHIBIT CRITERIA	ALERTING FUNCTIONS INHIBITED
DC-10	BELOW 100 FT RADIO ALTITUDE WHEN IN DUAL LAND MODE	<ul style="list-style-type: none"><li>● MASTER CAUTION AND MASTER WARNING LIGHTS</li><li>● AMBER AUTOPILOT OUT-OF-TRIM AND DISCONNECT LIGHTS</li><li>● AMBER AUTOTHROTTLE DISENGAGE LIGHTS</li></ul>

Figure 21 Inhibit Philosophies Applied to Subsystem Fault Annunciations

Applicable sections of the FARs are copied verbatim and tabulated in appendix A opposite the alerting functions to which they apply. In cases where the FARs specified a general requirement applicable to an entire system, the requirement was listed at the end of the tabulation for that system.

ARP 450 provides guidelines relative to the design of flight deck visual, audible, and tactile signals; ARP 571 specifies requirements for visual and aural alerts associated with nav/comm systems, and methods of annunciating flight director, autopilot, and autothrottle system operating modes; ARP 1068 specifies design objectives for all instrumentation and displays on the flight deck; and ARP 1161 specifies lighting and color requirements for each basic type of alert. DO-161A specifies minimum performance standards, including minimum alerting requirements for ground proximity warning systems. The alerting system requirements/guidelines contained in these standards are summarized in tables E-1, -2, -3, -4, and -5 (appendix E). Hardware requirements are not included. In most cases the requirement is copied verbatim; however, in a few cases, these statements are paraphrased to minimize similar statements.

The military standards and specifications do not provide specific requirements relevant to alerting systems in commercial transport category aircraft. These requirements are primarily of a general nature and not directly applicable unless referred to in a FAR or ARP. They do contain substantial human factors data pertinent to the design of alerting systems. The bulk of these data are covered in the survey of pertinent human factors data (section 2.4 and ref. 2). The key points in the remaining guidelines provided by these standards are listed in tables E-6, E-7, and E-8 of appendix E.

## **2.2.2 SURVEY OF PROBLEMS WITH CURRENT ALERTING SYSTEMS**

The International Air Transport Association (IATA) Technical Committee performed a study of the operational problems its member airlines had experienced with aircraft warning systems. They became concerned over the number of accidents that have occurred where the aircraft warning system was a factor or may have contributed significantly to the chain of casual events, and concluded that an analysis of these problems was required to protect present fleets and future aircraft from similar accidents. Unfortunately, no systematic effort had been made previously to collect detailed data regarding operational experiences with the warning systems found in current transport aircraft. As an initial step in this direction, IATA surveyed its member airlines to determine the current complement of cockpit warning systems in transport aircraft, and to identify problems experienced by airline crews with the functioning of these systems.

Dr. John Lauber at NASA Ames Research Center was commissioned to perform this survey for IATA. The survey covered 46 airlines operating the following aircraft:

- DC-3, DC-8, DC-9, and DC-10
- 707, 727, 737, and 747
- L-188 and L-1011
- F-27 and F-28

- A300B
- BAC-111 and VC-10
- SE 210, C-160P, YS-11A, and HS-748

Included in this fleet were 2614 aircraft.

The survey resulted in identification of 270 operational alerting system problems classified as follows:

- 146 false positive warnings
- 36 false negative warnings
- 74 system problems
- 9 display problems

False positive warnings are failures of the alerting system to notify the crew that a hazardous or abnormal situation demanding their attention existed. False negative warnings are nuisance alerts, i.e., an alert was given when no hazardous or abnormal situation existed.

The system problems consisted of all cases wherein the operators were forced by regulation to modify or voluntarily modified the basic alerting system to avoid specific operational problems.

The specific alerting system features that constituted each of these statistics were not identified in Dr. Lauber's study beyond the level shown in table 11. A more detailed analysis of these data by The Boeing Company was only partially completed during this study. No specific alerting system requirements evolved from the partial analysis. Completion of the detailed analysis is planned for the near future.

### 2.2.3 CORRELATION BETWEEN CHECKLIST AND ALERTS

A cursory review was made of the correlation between the number of alerts in each alerting classification (warning, caution, or advisory/status) and the number of checklists or procedures in each of the following procedure categories:

- Emergency checklists
- Abnormal checklists
- Additional procedures

Aural alerts were not considered in this survey because the alerting classification that each aural alert belongs in is questionable.

**Table 11 Alerting System Problems and Modifications Reported in IATA Survey of Airlines**

<b>WARNING SYSTEM CATEGORY</b>	<b>NUMBER OF OPERATIONAL PROBLEMS</b>	<b>NUMBER OF MODIFICATIONS</b>
<b>ENGINE/POWER SYSTEMS:</b>		
ENGINE FAILURE WARNING SYSTEM	10	6
ELECTRICAL SYSTEM WARNINGS	10	8
HYDRAULIC SYSTEM WARNINGS	6	3
PNEUMATIC SYSTEM WARNINGS	7	5
FUEL SYSTEM WARNINGS	6	3
<b>CABIN ENVIRONMENT SYSTEMS:</b>		
AIR-CONDITIONING WARNINGS	3	1
PRESSURIZATION SYSTEM WARNINGS	2	4
CABIN DOOR WARNINGS	27	12
OXYGEN SYSTEM WARNINGS	2	2
<b>ICE PROTECTION SYSTEMS:</b>		
WING ANTI-DE-ICE SYSTEM WARNINGS	3	2
ENGINE ANTI-ICE WARNINGS	4	0
PITOT/STATIC HEATING SYSTEM WARNINGS	10	4
OTHER WARNINGS	2	3
<b>FIRE DETECTION AND WARNINGS SYSTEMS:</b>		
ENGINE FIRE WARNINGS	34	20
AUXILIARY POWER UNIT FIRE WARNINGS	5	6
CARGO BAY FIRE WARNINGS	8	9
WHEELWELL FIRE WARNINGS	0	0
OTHER WARNINGS	4	2
<b>PRIMARY FLIGHT CONTROL SYSTEMS:</b>		
HORIZ STABILIZER MOVEMENT WARNINGS	6	4
FLAP AND SLAT SYSTEM WARNINGS	9	12
SPOILER WARNINGS	4	2
AILERON, ELEVATOR, RUDDER SYS WARNINGS	2	2
TAKEOFF CONFIGURATION WARNING SYSTEM	14	15
LANDING CONFIGURATION WARNING SYSTEM	16	9



**Table 11 Alerting System Problems and Modifications Reported in IATA Survey of Airlines (Cont)**

WARNING SYSTEM CATEGORY	NUMBER OF OPERATIONAL PROBLEMS	NUMBER OF MODIFICATIONS
<b>BRAKING SYSTEMS:</b>		
BRAKE OVERHEAT WARNINGS	5	0
ANTISKID FAILURE WARNINGS	5	2
REVERSE THRUST SYSTEM WARNINGS	11	4
<b>PRIMARY FLIGHT PERFORMANCE SYSTEMS:</b>		
STALL WARNING SYSTEM	10	8
MACH/OVERSPED WARNING SYSTEM	2	0
ALTITUDE AND TERRAIN WARNING SYSTEMS	1	0
BAROMETRIC ALTITUDE DEVIATION	6	7
RADIO ALTITUDE WARNING	0	11
GROUND PROXIMITY WARNING	0	13
<b>INSTRUMENT FAILURE WARNING SYSTEMS:</b>		
FLIGHT INSTRUMENT COMPARATOR WARNING	9	8
FLIGHT INSTRUMENT FAILURE WARNINGS	6	5
NAVIGATION INSTRUMENT FAILURE WARNINGS	3	2
ENGINE/POWER INSTRUMENT FAILURE	3	0
<b>AUTOPILOT SYSTEM WARNINGS</b>	<b>9</b>	<b>8</b>

The category **ADDITIONAL PROCEDURES** includes all procedures listed in the flight operations manual that do not warrant a distinct checklist in the pilot's checklist summary booklet but are required for the crew to remedy aircraft malfunctions. Normal checklists, such as engine start, landing, secure, etc., also are not included in this category because their design is very dependent on the nature of each airline's operation.

Table 12 specifies the number of alerts and checklists or procedures that fall into each of these categories. Table 13 specifies the ratio of alerts to checklists and procedures in each category. No correlative pattern between the application of alerts and the usage of checklists was discerned in these data. However, the ratio of warning-type alerts to emergency procedures nearly doubled with the advent of wide body aircraft. This ratio jumped from an average of 4.5 for narrow body aircraft to an average of 8.8 for wide body aircraft. The difference apparently developed because of requirements for additional red lights and flags to annunciate the failure modes of more complex autopilot systems incorporated in wide body aircraft. No emergency checklist is usually associated with these autopilot failure situations.

The correlation between the type of checklist and the type of alert applied to each situation also was analyzed. The analysis showed that the majority of the checklists do correlate with the color of the alert light(s) used to annunciate the situation. However, several examples of noncorrelation were

Table 12 Correlation Between Number of Alerts and Number of Checklists

TYPE OF ALERT	NUMBER OF ALERTS AND CHECKLISTS PER AIRCRAFT TYPE								
	707	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
WARNING	70	69	49	109	85	81	127	118	39
CAUTION	118	197	153	346	87	123	291	385	44
ADVISORY/ STATUS	105	103	115	302	59	40	208	295	13
TYPE OF CHECKLIST/ PROCEDURES	14	17	12	16	16	17	12	13	11
	15	15	50*	26	76	27	46	25	26
	130	94	—	74	—	83	37	84	—

\*THIS AIRLINE COMBINED ALL NONEMERGENCY CHECKLISTS AND PROCEDURES INTO THE ABNORMAL CHECKLIST CATEGORY.

**Table 13 Ratio of Alerts to Checklists and Procedures**

	707	721	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
<u>WARNING ALERTS</u> <u>EMERGENCY PROCEDURES</u>	5.0	4.1	4.1	6.8	5.3	4.8	10.6	9.1	3.6
<u>CAUTION ALERTS</u> <u>ABNORMAL PROCEDURES</u>	7.9	13.1	3.1	13.3	1.1	4.6	6.3	15.4	1.7
<u>ADVISORY ALERTS</u> <u>ADDITIONAL PROCEDURES</u>	0.8	1.1	—	4.1	—	0.5	5.6	3.5	—

also found. On the 737, for example, an abnormal checklist is associated with the two blue lights that annunciate "generator breaker tripped open." On the BAC-111, an abnormal checklist is associated with the two red lights that annunciate "fuel boost pump low pressure." A definite correlation between the type of alert and the type of checklist or procedure applied to each situation should be established. If an emergency procedure is required, a warning-type alert should be used to annunciate the situation and if an abnormal procedure is required, a caution-type alert should be used. Advisory and status lights should be used to annunciate situations that do not require crew action and/or do not have a specific corrective or compensatory procedure associated with them. The reverse of these situations also should be applied, e.g., a warning-type alert should not be used unless an emergency procedure is required. Again, a definite correlation of these functions needs to be established.

#### **2.2.4 PILOT PREFERENCES**

A survey of several pilot organizations resulted in the following consensus relevant to the design of alerting systems:

- Reduce the number of alerts, especially the number of aural alerts.
- Most aural alerts, as currently designed, are too loud.
- Noncritical alerts should be inhibited during high workload periods, such as takeoff and flare/landing.
- Selected alerts should be prioritized.
- Audio-visual characteristics of the alerts should be designed to instantaneously inform the pilot of the criticality of the situation.
- Direct correlation between the type of alerts and the type of checklists should be established, i.e., warning and emergency, caution and abnormal, etc.

The survey included ALPA representatives and chief technical pilots from most large airlines, plus pilots from the Boeing, McDonnell Douglas, and Lockheed flight test organizations and the Boeing crew training organization.

The pilots unanimously agree that the current number of aural alerts is excessive and provides the potential for confusion in the cockpit. Even the most proficient pilots questioned whether they, in a high-stress situation, could rapidly interpret the significance of some of the less frequently heard aural alerts. They indicated that part of the confusion is caused by multifunction applications of some of the aural alerts, i.e., designing the alerting system such that an aural alert has one meaning during takeoff and another meaning during airborne operations. The number of aural alerts acceptable to most pilots is four, preferably one. If four aural alerts are used, they must be four familiar alerts.

The intensity of many currently used aural alerts is too high. Most aural alerts are so loud that normal crew coordination cannot be carried on. Their intensity should be reduced and/or a manual cutoff capability should be provided.

Many of the pilots felt that the potential for too many noncritical alerts exists in the critical operating regimes where the crew cannot afford to divert their attention from the primary flying tasks. The pilots were particularly concerned about distracting alerts in the following two flight regimes:

- Takeoff (from slightly below  $V_1$  through climb to several hundred feet altitude)
- Landing (from 200 feet altitude through braking and thrust reverse)

An inhibit scheme of the type shown in figure 22 was suggested.

Inhibits were also suggested for the following purposes:

- Minimize nuisance alerts by inhibiting appropriate sections of the alerting system in flight phases wherein the alert has no meaning
- Override background noise, such as radio chatter, that interferes with aural alerts
- Method of prioritizing alerts

The application of inhibits to suppress nuisance alerts and to prioritize alerts received extensive pilot support. However, the concept of inhibiting radio communications when an aural alert is activated received numerous objections; the pilots were wary of the potential failure mode wherein the alerting system could inhibit their radio communication capability.

The majority of these pilots also felt that alert effectiveness could be improved by selective prioritization. The alerts should be grouped into three or four categories wherein each category denotes a level of criticality. Alerts within each category should also be prioritized. The capability for an alert to transition from one category to another as a function of flight phase should be incorporated into the priority system. The priority of the alerts will vary from one aircraft to another. Accordingly, variable prioritization capability must be provided.

These pilots favored prioritization; however, they could not define criteria for when prioritization was necessary. In a very simple alerting system, prioritization might not be required; in a complex alerting system, prioritization probably would be beneficial.

A unique audio-visual method of alerting should be associated with each priority category so as to provide an instantaneous assessment of the situation's criticality. Current alerting systems do not provide this information, thereby necessitating somewhat drastic methods of alerting for the highest priority alerts. The need for drastic alerting methods should be eliminated by incorporating this alerting system characteristic.

The pilots expressed concern over the lack of correlation between the type of alert and the type of checklist applied to each situation. They want emergency checklists to be associated with warning-type alerts, abnormal checklists to be associated with caution-type alerts, and the additional procedures specified in the flight operations manual to be associated with the advisory/status alerts.

Other preferences were also expressed by the pilots; however, none as strongly or as uniformly as these six points.

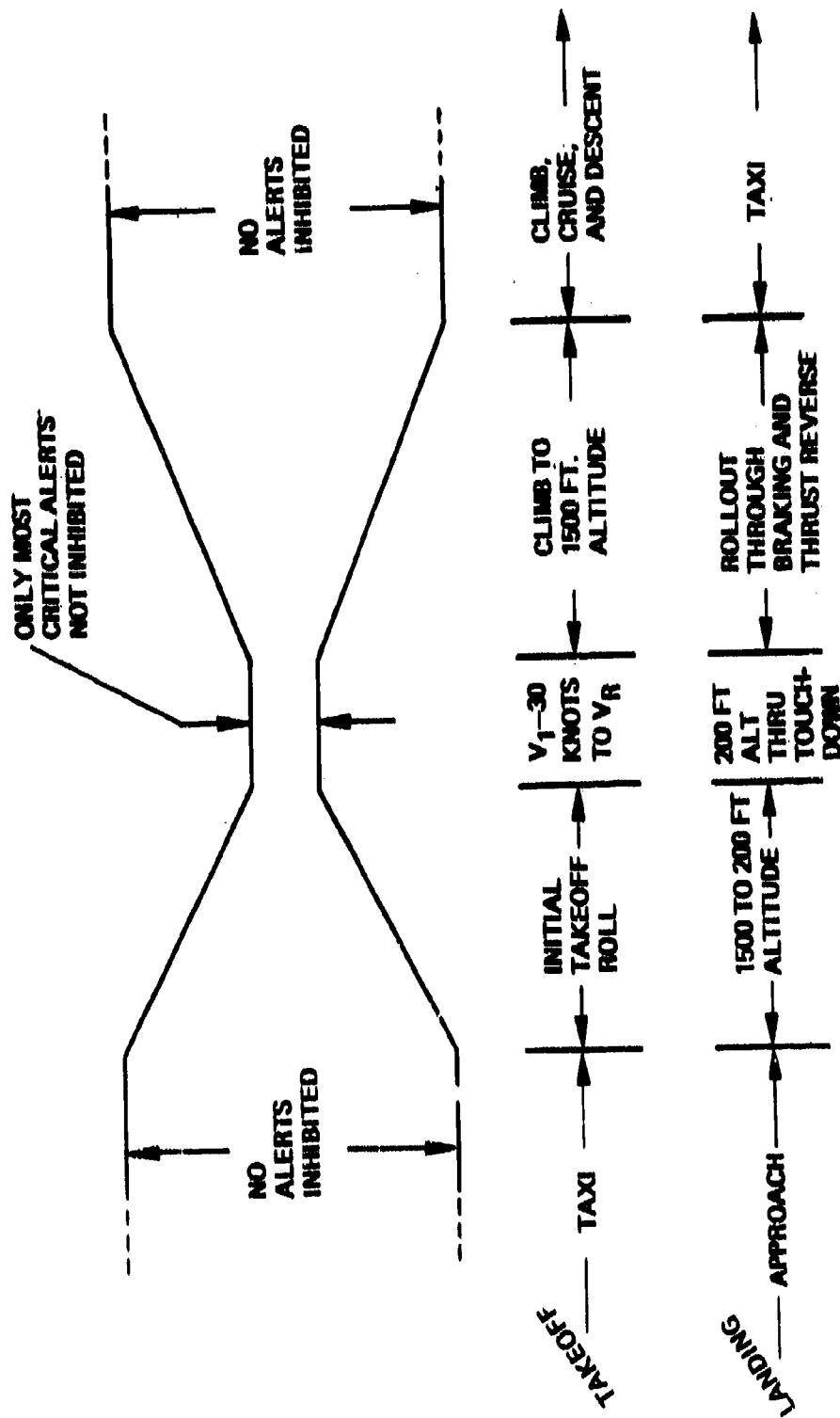


Figure 22 Alert Inhibit Scheme

## 2.3 ALERTING FUNCTION CATEGORIES AND PRIORITIES

The requirements established in previous sections were utilized in this portion of the study to (1) define alerting function categories, (2) develop a method for assigning alerting functions to these categories, and (3) develop a method for prioritizing the alerting functions within each category. The validity of these definitions and category/priority allocation methods was tested by (1) applying them to a 737 and (2) noting conflicts between established standards and the results of the application. Each of these tasks is discussed in detail in the following sections.

### 2.3.1 CATEGORY AND PRIORITY DEFINITIONS

Many cockpit designers and pilots believe that current alerting system problems could be resolved if firm category definitions and requirements to design to these definitions were established. Attempts at establishing firm definitions for alerting categories were made long before the current study. Thus, a historical review of recent developments in this subject will be utilized to develop the rationale for the category definitions and prioritization methods proposed by this study.

Two SAE standards--ARP 450 and ARP 1068--established a set of groundrules for mechanizing alerting systems encompassing single-function aural alerts, discrete visual alerts, a master caution system, and a master warning system. No alerting categories or priority schemes were established in these standards.

During the era in which the aircraft analyzed by this study were designed, these ARP standards often were not adhered to because they had not been updated to reflect latest methods of implementing cockpits. This lack of operational guidelines resulted in each airframer and each operator developing and implementing their own unique alerting system philosophy. Pilot encouragement finally caused the SAE S-7 Committee to direct their attention to updating these ARP standards and the FAA to initiate this research program which is aimed at developing a universally agreed to set of design objectives/guidelines for alerting systems.

The SAE S-7 committee, "Flight Deck and Handling Qualities Standards for Transport Category Aircraft," recognized this flaw in their standards and requested inputs from the airlines and airframe manufacturers. Boeing responded with two proposed sets of alerting system categories plus a list of typical alerting functions that fall within each category. SAS airlines responded with a dissertation on alerting system implementation requirements. Copies of both responses are provided in appendix F.

The Boeing response (see section F.1) provided a "first-cut" at categories that were oriented toward importance of the alert rather than the categories of configuration, flight profile, and systems as had been suggested by earlier studies. Three basic levels of importance (categories) were established therein:

- LEVEL 1     Highest priority alerts requiring immediate crew action. It was recommended that the dedicated alerting systems currently used for these functions be retained.
- LEVEL 2     Safety of flight items requiring crew action but not immediately. Three sublevels were defined in this category. LEVEL 2-A consisted primarily of alerts currently annunciated by an aural alert; LEVEL 2-B consisted primarily of system malfunctions and

aircraft misconfigurations with which the pilot would not want to take off with; and LEVEL 2-C consisted primarily of aircraft misconfiguration items that should be corrected prior to taxiing.

**LEVEL 3** Checklist items that have only a minor effect on safety of flight. Included passenger service items.

The requirement for a central readout device that identifies the nature of each alert and provides for graduations in the boldness of the alert was established therein.

In an attachment, Boeing also proposed a secondary set of category definitions based on crew recognition and action requirements. This concept identified the various types of pilot responses that are required and suggested alerting methods that would provide such response.

The SAS response (see section F.1) to the SAE S-7 committee's request for guidelines relevant to the operation and design of alerting systems was very similar to Boeing's but did not provide category definitions. Both responses indicated a need for (1) minimizing the application of discrete aural alerts and (2) an alphanumeric display located in front of each pilot that describes the exact nature of the alerted situation. SAS also provided a detailed description of how the central alphanumeric display should operate.

The FAA simultaneously initiated a series of studies aimed at developing standards for alerting systems in new aircraft. This study is one of that series. Based on knowledge acquired in earlier phases of this study, two more detailed alert category definitions were suggested (see section F.2, appendix F). These category definitions were amplifications of the alerting levels suggested earlier and as integrated by Boeing engineers as opposed to Boeing pilots. A slight diversity of opinion existed between the two groups; however, the fundamentals of both concepts were identical.

A numerical method of analyzing the criticality of each alerting situation and accordingly assigning it to an alerting category was then sought. The purpose of resorting to a numerical method was to eliminate the subjective aspects of assigning alerting categories. The relationship between the probability of an alerting situation occurring and the severity of its effects, as established in BCAR paper number 670, was used as a basis for this numerical method. Figure F-1 in appendix F defines this relationship as applied to alerting systems. The numerical method consisted of calculating the probability of a failure or hazardous situation occurring in conjunction with (1) the crew not recognizing the alert and (2) the situation resulting in injuries, as a function of time, and then equating the resulting probability value to the levels specified in figure F-1. The resulting probability value defined the type of alert required. Figure F-2 defines this relationship.

Several potential problems were encountered with the probability method of categorizing and prioritizing alerting functions:

- How to compensate for pilot latency?
- How to distinguish between major and catastrophic events?
- What crew workload level to assume?



- What "time allowance for corrective crew action" distinguishes a warning from a caution?
- Should "crew reliability" be utilized to design and certify aircraft systems?

No substantive answer exists to the first four questions. The answers to the questions were very dependent on subjective opinions. The last question is dominated with many legal implications. Thus, although the probability method of categorizing and prioritizing alerting functions is viable, it was abandoned.

Nonquantitative methods of prioritization and the definition of firmer nonnumerical categorization/prioritization criteria were then resorted to again. Two more sets of category criteria were proposed. A Boeing engineer proposed the four category definitions defined in table F-2 (appendix F). The key factor in this proposal was the definitions of crew recognition and response time requirements. The SAE S-7 committee simultaneously developed the alerting system philosophy and category criteria defined in section F-5. The comments of Swissair's chief technical pilot on the SAE S-7 committee's alerting system philosophy are also provided. These three concepts were integrated to formulate the category criteria defined in table 14.

The category criteria provide guidelines for cockpit designers to roughly prioritize the alerting functions. However, they do not provide a detailed method for analyzing the priority of each alerting situation as a function of flight phase and within each category. An air-conditioning systems failure, for example, would have higher priority during cruise than during takeoff or final approach. During final approach the crew is almost totally occupied with flying the aircraft down the ILS and landing. Annunciation of an air-conditioning failure during cruise could result in a very uncomfortable situation of the remainder of the flight. The crew usually is not busy during this time period and would try to remedy the air-conditioning problem promptly.

The impact of various types of alerts on the crew's primary tasks during each of the following flight phases were analyzed:

- |                |                     |
|----------------|---------------------|
| ● Preflight    | ● Cruise            |
| ● Engine start | ● Descent           |
| ● Taxi         | ● Approach          |
| ● Takeoff      | ● Landing           |
| ● Climb        | ● Taxi and shutdown |

Note that in a practical situation this many flight phases probably would not be used. For this analysis, excess detail was felt to be better than lack of detail. Therefore, since the optimum combination of flight segments was not known, excessive segmentation was used.

**Table 14 Criteria for Categorizing Alerting Functions**

LEVEL	CONDITION	CRITERIA
1	EMERGENCY (WARNING)	EMERGENCY OPERATIONAL OR AIRCRAFT SYSTEMS CONDITIONS WHICH REQUIRE <u>IMMEDIATE</u> CORRECTIVE OR COMPENSATORY ACTION BY THE CREW.
2	ABNORMAL (CAUTION)	ABNORMAL OPERATIONAL OR AIRCRAFT SYSTEMS CONDITIONS WHICH REQUIRE <u>IMMEDIATE</u> CREW AWARENESS AND REQUIRE CORRECTIVE OR COMPENSATORY CREW ACTION.
3	ADVISORY	OPERATIONAL OR AIRCRAFT SYSTEMS CONDITIONS WHICH REQUIRE CREW <u>AWARENESS</u> AND MAY REQUIRE CREW ACTION.
4	INFORMATION	OPERATIONAL OR AIRCRAFT SYSTEMS CONDITIONS WHICH REQUIRE COCKPIT INDICATION BUT NOT NECESSARILY AS PART OF THE INTEGRATED WARNING SYSTEM.

This analysis showed that a considerable change in the crew's level of concentration on their primary flying tasks occurs midway through each of these flight phases. During takeoff for example, the crew's concentration on the takeoff flying tasks increases as  $V_1$  is approached, remains very high through rotation and climb to a safe altitude, and then decreases again. A period of GO/NO GO uncertainty also exists during takeoff roll from approximately 30 knots prior to  $V_1$  or  $V_R$ . Any noncritical alert during this period would disturb the crew and possibly cause the pilot to make an erroneous GO/NO GO decision. Only the most critical situations with which the crew would not

want to take off should be annunciated during this period. A similar situation exists in the landing phase wherein the crew should not be disturbed during the last 200 feet of descent, flare, and touchdown. Distinctions also exist between operations above and below 14,000 feet altitude due to aircraft pressurization requirements.

Ground maintenance operations were reviewed and found to require many of the same alerting functions that the flight crews need. When trimming an engine, for example, the maintenance crew requires all the engine malfunction and fire protection alerts. However, the criticality of these functions may not be as high in maintenance operations as in flight operations.

Based on these types of analyses, the flight phases or flight-phase segments defined in table 15 were selected for further prioritizing the alerting functions. The two problems that still remained were (1) how to prioritize compound malfunctions and (2) how to prioritize the alerting functions within each category.

The compound malfunction situation is very aircraft and type of system dependent. The failure, for example, of one hydraulic system does not pose as critical a situation on the 747 as on the 737 because the 747 has four parallel hydraulic systems, whereas the 737 has only two parallel systems. Is the failure of two hydraulic systems or three hydraulic systems on the 747 equivalent to the failure of a single system on the 737? Figure 23 illustrates the general type of logic that had to be applied to prioritize these alerting situations. The logic in this diagram was developed primarily for nonavionics systems. The general application of this logic to all systems, however, is not feasible. In attempts to develop and verify prioritization logic of this type, it was determined that parallel sets of logic were required—one set of logic for each type of system malfunction and operational situation. The development of these detailed prioritization logic sets required more expertise on the compound effects and safety implications of each alerting situation than was available to the group performing this study. An analysis of the effects and safety implications of each compound malfunction was required for each basic type of aircraft in order to assign relative priorities to these alerting situations.

Similar situations arise with regard to compound malfunctions involving various types of systems. For example, what should the priority be of an alert annunciating a pneumatic system failure after an air-conditioning system failure has already occurred? Should it be the same priority as, or a higher priority than, a pneumatic system failure without any previous air-conditioning failures? Another example, how should the relative priorities of an autopilot channel failure as compared to an electrical generator be established? The electrical generator failure would have broader effects on operation of other aircraft systems, including the autopilot, but the autopilot could have an immediate effect on controlling the flightpath of the aircraft. Which is more important?

Some pilots argue that compound effects should not be considered in prioritizing the alerts. The priority assigned to the basic alerting function should be used for all situations, irrespective of compound effects, and the assessment of compound effects should be left up to the pilots. Other pilots want an elaborate alerting system that makes all the compound effect judgments for them. The analyses performed in this study indicate that the elaborate versions of the system would:

- Require substantial computation capability
- Require software that is very sensitive to aircraft configuration modifications and frequent modifications of this software to keep it current (as with the checklists)

**Table 15 Flight Phases Used in Prioritizing Alerting Functions**

DEFINITION	COMMENTS
GROUND MAINTENANCE	<p>PRIOR TO ENGINE START</p> <p>PRIOR TO TAXI</p> <p>PRIOR TO APPLYING TAKEOFF THRUST</p> <p>PRIOR TO ATTAINING A SPEED OF <math>V_1-30</math> KNOTS</p> <p>DURING ACCELERATION FROM <math>V_1-30</math> TO <math>V_R</math></p> <p>FROM <math>V_R</math> THROUGH ROTATION AND CLIMB TO 1500 FT</p> <p>BETWEEN 1500 AND 14,000 FT ALTITUDE</p> <p>OPERATIONS ABOVE 14,000 FT</p> <p>FROM 1500 TO 200 FT ALTITUDE</p> <p>FROM 200 FT ALTITUDE THROUGH FLARE, TOUCHDOWN AND SPEED REDUCTION TO TAXI SPEED</p>
PREFLIGHT	
ENGINE START	
TAXI	
INITIAL TAKEOFF ROLL	
FINAL TAKEOFF ROLL	
INITIAL CLIMB	
LOW-ALTITUDE CLIMB, CRUISE, OR DESCENT	
HIGH-ALTITUDE CLIMB, CRUISE, OR DESCENT	
APPROACH	
LANDING	
TAXI AND SHUTDOWN	

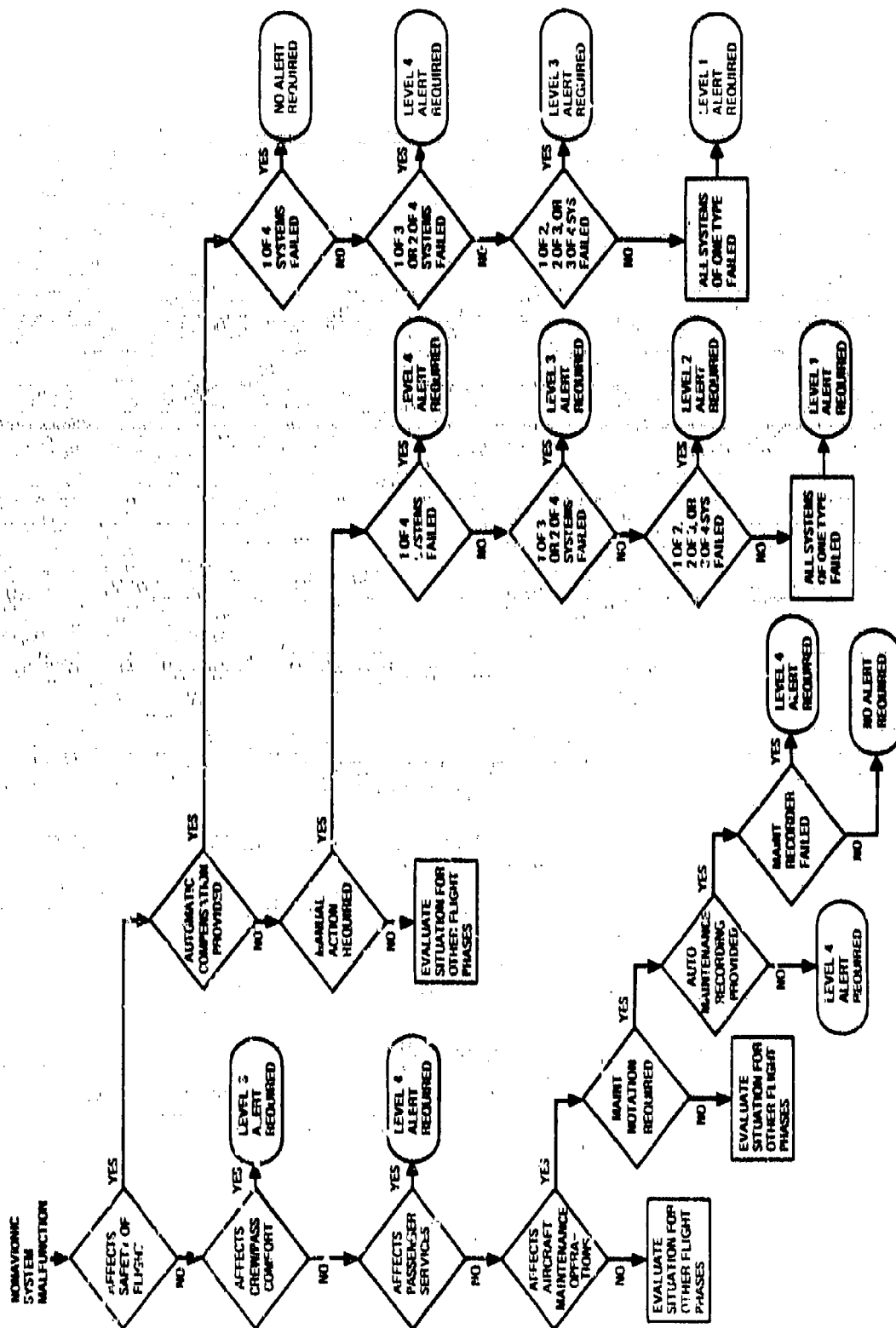


Figure 23 General Type of Logic: Required to Prioritize Alerting Functions

- Make the logic unique to each aircraft—differences could exist between aircraft of the same type, even within an airline's fleet

The elaborate version of the system could become an expensive maintenance item for the airlines. For these reasons, therefore, it is recommended that alert prioritization as a function of compound effects be minimized.

The prioritization of alerts within each category was also studied. An example of such a case is prioritization of the stall warning relative to the ground proximity warning. Both alerts will probably be LEVEL 1 alerts as defined in table 14. If a ground proximity warning occurs and then a stall warning occurs while the pilot is pulling up, should the stall warning take precedence, should the ground proximity warning take precedence, or should both be allowed to occur simultaneously? Ideally, a numerical rating method would be utilized to prioritize these alerting functions within each category; however, none was conceived. The ranking of these alerts is very subjective; pilot opinion on these rankings currently is diverse. Much of the diversity results from differences in the designs of the aircraft. However, better agreement exists among the high priority alerting functions than on the middle or low priority alerts. Thus it is recommended that priority sequence guidelines be established only for the LEVEL 1 and possibly LEVEL 2 alerts, and that the prioritization of LEVEL 3 and LEVEL 4 alerts to be left up to the airframe manufacturers and operators.

### 2.3.2 APPLICATION OF CATEGORY/PRIORITY RATIONALE

Category criteria for defining alert priorities were specified in table 14. The flight phases and flight phase segments for which alert priorities have to be specified were defined in table 15. Consideration of compound effects was deemed unnecessary. Standardization on alert priorities within the categories was deemed feasible only within the two highest priority alert categories. The low priority alerts are too dependent on aircraft design differences to allow standardization. These alert prioritization philosophies were applied to a 737 to validate the concepts and to identify conflicts with existing standards.

Each alerting function specified in appendix A for the 737 was assigned a priority as a function of flight phase (see appendix G). The alerting functions within LEVELS 1 and 2 were then prioritized as shown in table 16. Note that prioritization of the LEVEL 3 and LEVEL 4 alerts was not attempted because these alerts are too aircraft design dependent. Significant differences in the alert priorities will exist in these two categories between aircraft models.

## 2.4 HUMAN FACTORS DESIGN GUIDELINES

In section 2.1, current alerting methods were reviewed and the good and bad features of each design were discussed. In section 2.2, existing standards, operational data, and pilot preferences were analyzed to obtain a composite listing of requirements that apply to existing alerting systems and to develop an alternate set of requirements that should be applied to future alerting systems. In section 2.3, alerting function category criteria and a set of alert priorities matching these criteria were established. The problem that then remained was "what human factors guidelines should be applied when implementing the results of these analyses?" A survey of the human factors data applicable to alerting systems was performed to develop these missing guidelines. The derivation of these guidelines and the types of data required to complete and validate these guidelines are discussed in the following sections.

Table 16 Example Application of Alerting Function Prioritization

ALERT LEVEL (CATEGORY)		1. EMERGENCY (WARNING)
ALERT PRIORITIES AS FUNCTION OF FLIGHT PHASE	GROUND MAINTENANCE	1. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT 2. UNSAFE TAKEOFF CONFIGURATION 3. STALL WARNING 4. GROUND PROXIMITY WARNING
	PRE-FLIGHT	1. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT
	ENGINE START	1. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT
	TAXI	1. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT
	INITIAL TAKEOFF ROLL	1. UNSAFE TAKEOFF CONFIGURATION 2. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT
	FINAL TAKEOFF ROLL	
	INITIAL CLIMB	1. STALL WARNING 2. GROUND PROXIMITY WARNING
	1500 TO 14,000 FT ALTITUDE	1. STALL WARNING 2. GROUND PROXIMITY WARNING
	ABOVE 14,000 FT	1. STALL WARNING 2. GROUND PROXIMITY WARNING 3. PRESSURIZATION FAILURE
	APPROACH 1500-300 FT ALT	1. STALL WARNING 2. GROUND PROXIMITY WARNING 3. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT 4. UNSAFE LANDING CONFIGURATION
	LANDING (BELOW 200 FT)	1. STALL WARNING 2. GROUND PROXIMITY WARNING 3. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT 4. UNSAFE LANDING CONFIGURATION 5. AUTOPILOT DISCONNECT
	TAXI AND SHUTDOWN	1. GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT

NOTE: ALERTS PRIORITIZED AS NUMBERED. NUMBER 1 HAS HIGHEST PRIORITY.

Table 16 Example Application of Alerting Function Prioritization (Cont)

ALERT LEVEL (CATEGORY)		2. ABNORMAL (CAUTIONS)	
GROUND MAINTENANCE RANGE	1. FINE WARNING	2. EGT OVERTEMP	6. PROXIMITY OVERTEMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	7. BLEED AIR TEMP HIGH
	3. FINE WARNING	4. OIL TEMP HIGH	8. COMPRESSOR TIME OVERHEAT
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	9. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	10. EXCESSIVE AIRSPEED ON RAMP
PRE FLIGHT	1. FINE WARNING	2. AIR CONDITIONING DUCT OVERHEAT	11. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. PROXIMITY OVERTEMP	12. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. PROXIMITY OVERTEMP	13. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. PROXIMITY OVERTEMP	14. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. PROXIMITY OVERTEMP	15. EXCESSIVE AIRSPEED ON RAMP
ENGINE START	1. FINE WARNING	2. EGT OVERTEMP	16. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	17. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	18. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	19. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	20. EXCESSIVE AIRSPEED ON RAMP
TAXI	1. FINE WARNING	2. EGT OVERTEMP	21. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	22. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	23. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	24. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	25. EXCESSIVE AIRSPEED ON RAMP
INITIAL TAKEOFF ROLL	1. FINE WARNING	2. EGT OVERTEMP	26. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	27. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	28. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	29. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	30. EXCESSIVE AIRSPEED ON RAMP
FINAL TAKEOFF ROLL	1. FINE WARNING	2. EGT OVERTEMP	31. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	32. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	33. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	34. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	35. EXCESSIVE AIRSPEED ON RAMP
INITIAL CLIMB	1. FINE WARNING	2. EGT OVERTEMP	36. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	37. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	38. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	39. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	40. EXCESSIVE AIRSPEED ON RAMP
HOLD TO 1400 FT ALTITUDE	1. FINE WARNING	2. EGT OVERTEMP	41. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	42. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	43. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	44. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	45. EXCESSIVE AIRSPEED ON RAMP
ABOVE 4000 FT	1. FINE WARNING	2. EGT OVERTEMP	46. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	47. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	48. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	49. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	50. EXCESSIVE AIRSPEED ON RAMP
APPROACH 1400 FT ALT	1. FINE WARNING	2. EGT OVERTEMP	51. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	52. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	53. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	54. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	55. EXCESSIVE AIRSPEED ON RAMP
LANDING 1400 FT AND 1700 FT	1. FINE WARNING	2. EGT OVERTEMP	56. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	57. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	58. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	59. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	60. EXCESSIVE AIRSPEED ON RAMP
TAXI AND SHORT-TERM FLIGHT	1. FINE WARNING	2. EGT OVERTEMP	61. EXCESSIVE AIRSPEED ON RAMP
	2. FINE WARNING	3. BLEED AIR TEMP HIGH	62. EXCESSIVE AIRSPEED ON RAMP
	3. FINE WARNING	4. OIL TEMP HIGH	63. EXCESSIVE AIRSPEED ON RAMP
	4. FINE WARNING	5. AIR CONDITIONING DUCT OVERHEAT	64. EXCESSIVE AIRSPEED ON RAMP
	5. FINE WARNING	6. AIR CONDITIONING DUCT OVERHEAT	65. EXCESSIVE AIRSPEED ON RAMP

NOTE: ALERTS PRIORITIZED AS NUMBERED. NUMBER 1 HAS HIGHEST PRIORITY



**Table 16 Example Application of Alerting Function Prioritization (Cont)**

ALERT LEVEL		3 ADVISORIES	4 INFORMATION (NOT PART OF INTEGRATED WARNING SYSTEM)
ALERT PRIORITIES AS FUNCTION OF FLIGHT PHASE	GROUND MAINTENANCE		
	PRE-FLIGHT		
	ENGINE START		
	TAXI		
	INITIAL TAKEOFF ROLL	FUNCTION OF AIRCRAFT DESIGN PRIORITIES TO BE DETERMINED BY AIRFRAME MANUFACTURER & OPERATOR	FUNCTION OF AIRCRAFT DESIGN PRIORITIES TO BE DETERMINED BY AIRFRAME MANUFACTURER & OPERATOR
	FINAL TAKEOFF ROLL		
	INITIAL CLIMB		
	1500 TO 14,000 FT ALTITUDE		
	ABOVE 14,000 FT		
	APPROACH (1800-200 FT ALT)		
	LANDING (BELOW 200 FT)		
	TAXI AND SHUTDOWN		

## 2.4.1 LITERATURE REVIEW AND RECOMMENDED GUIDELINES

The literature review was structured to investigate how pilots respond to alerting signals. The current variety of signaling devices utilized to transfer information in the cockpit have begun to saturate the pilot and decreased his efficiency to the point where prioritization of the information presented may be necessary. The basis for any prioritization scheme must be the time in which a pilot must react to the situation. Signaling devices must be selected to ensure a response time that is commensurate with the priority of the signal and must convey enough information to maximize the probability of the correct response within a reasonable time. Since current aircraft design practices for alerting systems have evolved with some nonoptimum characteristics due to cost, implementation difficulties, or personal biases of various chief pilots and designers, the literature review was performed with a ground rule to "ignore current aircraft design practices."

The literature review was conducted with the following specific objectives:

- Investigate the type of signals that can be used to transfer information in a cockpit environment.
- Determine the factors that affect the detection of these signals.
- Determine the factors that affect the time from signal detection to a correct action.
- Formulate guidelines for maximizing the effectiveness of signaling systems.
- Evaluate the data with respect to its relevance and applicability and recommend research programs to augment the existing data and refine the guidelines.

The review was divided into two primary areas of concern:

- Factors that affect detection of signals
- Factors that affect time from detection to correct response

The literature review and guidelines are quite lengthy and will therefore only be presented in a condensed form in this section; the full text is contained in reference 2.

### 2.4.1.1 Factors That Affect Detection of Signals

A summary of the factors that affect visual, auditory, and tactile signals is presented in table 17. These data indicate that the detection of visual signals is affected by the signal location, size, brightness, color, and steady state or intermittent nature.

The location of a visual signal relative to the pilot's centerline of vision has a significant effect on not only the speed with which a signal is detected, but also the probability that it will be seen at all.

Evidence indicates that the likelihood of detecting a small visual signal decreases from 83% for those alerts located directly in the center of the pilot's visual field to 35% for those signals located in the 30° to 40° deviation zone.

**Table 17 Stimuli Response Sensitivities and Applications Guidelines Summary**

STIMULUS	CHARACTERISTIC	SENSITIVITY/APPLICATION GUIDELINE
VISUAL	LOCATION	15° FROM LINE OF SIGHT (MAX)
	SIZE	1° VISUAL ANGLE
	BRIGHTNESS	BRIGHTER THAN BACKGROUND BUT NOT SO BRIGHT AS TO BLIND OBSERVER
	FLASHING VS STEADY	FLASHING AGAINST STEADY BACKGROUND MOST EFFECTIVE
	COLOR	<p>FAST<sup>ST</sup> ← ————— → SLOWEST</p> <p>RED      GREEN      YELLOW      WHITE</p> <p>1.8 SEC   2.0 SEC   2.3 SEC   2.7 SEC → DETECTION TIMES</p>
AUDITORY	PERCEIVED LOUDNESS	MAXIMIZED IN 2000 TO 4000 H <sub>z</sub> RANGE
	FREQUENCY DEAFNESS	USE TWO OR MORE FREQUENCIES IN 250 TO 4000 H <sub>z</sub> RANGE WITHIN EACH SIGNAL
	SOUND LEVEL	15 dB ABOVE MASKING THRESHOLD OR HALFWAY BETWEEN MASKING THRESHOLD AND 110 dB, WHICHEVER IS LESS
	LOCATION	<p>MONAURAL SIGNALS SHOULD BE PRESENTED TO DOMINANT EAR</p> <p>WARNING SIGNAL SOURCE SHOULD BE SEPARATED AT LEAST 90° FROM THE SOURCE OF INTERFERING NOISE OR MESSAGES</p>
	INTERMITTENT VS STEADY	INTERMITTENT MORE LIKELY TO BE DETECTED
	MESSAGE CONTENT	PRECEDE MESSAGES BY AN ATTENTION GETTER TO WHICH THE PILOT IS MORE THAN NORMAL SENSITIVE
TACTILE	INTERMITTENT VS STEADY	TOUCH SENSE IS ACTIVATED ONLY BY SKIN DEFORMATION
	VIBRATION	MAXIMUM SENSITIVITY BETWEEN 200 AND 300 H <sub>z</sub>
	AREA OF BODY	FINGERS MOST SENSITIVE BUTTOCKS LEAST SENSITIVE
	INTENSITY	50 TO 100 MICRONS

The military standards and design guides define the pilot's centerline of sight as a vector emanating from the pilot's eye, extending straight forward and angled  $10^\circ$  below horizontal. The commercial airframe manufacturers have several definitions of the centerline of sight, all of which differ from the military definition. The most consistently used commercial aircraft definition of centerline of sight appears to be the line between the pilot's eye reference point and the center of his ADI. The definitions of primary and secondary field of view also vary. The military defines primary field of view as the region within a  $15^\circ$  cone around the centerline of vision and the secondary field of view as the region between a  $15^\circ$  and a  $30^\circ$  cone around the centerline of vision. Commercial aircraft manufacturers generally define primary field of view as a binocular-shaped area covering most of the pilot's primary instrument panel (containing ADI, HSI, airspeed, and altitude indicators) and secondary field of view as a binocular-shaped area covering most of the pilot's front panel (including engine instrument and autopilot mode select panels). Considerable variations of these definitions were found in the commercial aircraft industry. The human factors data indicate that most of these definitions are reasonable with respect to location of alerting signals. However, until further testing can be performed to better define these criteria, the following combination of military and commercial criteria for location of visual alerting signals is recommended:

- High priority alerts should be located no more than  $15^\circ$  from the pilot's centerline of vision.
- Caution signals should be located no more than  $30^\circ$  from the pilot's centerline of vision.

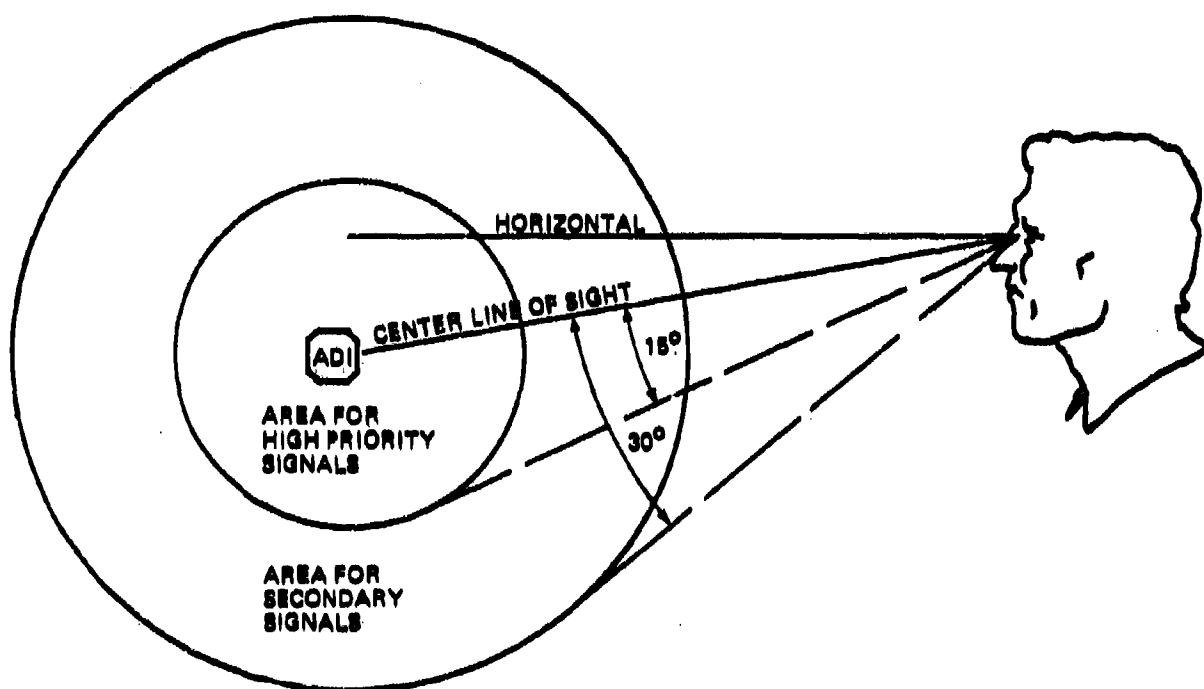
To summarize, the higher priority a visual signal is, the closer it should be located to the center of the pilot's visual field. An illustration of these guidelines is provided in figure 24.

The size of the visual signal also has a strong effect on its detection time. Figure 25 presents the effect of increasing the lighted area of a border-lit signal. A moderate improvement in response time is obtained when the border width was increased from  $0.26^\circ$  visual angle (1 square degree of surface area) to  $0.64^\circ$  (2.74 square degrees). However, there is essentially no improvement beyond this point. Other research efforts have also found this signal size of  $1^\circ$  visual angle produces the quickest response times. Therefore it is recommended that: (1) high-priority signals be no less than  $1^\circ$  visual angle in size, and (2) secondary signals be no less than  $0.5^\circ$  visual angle in size.

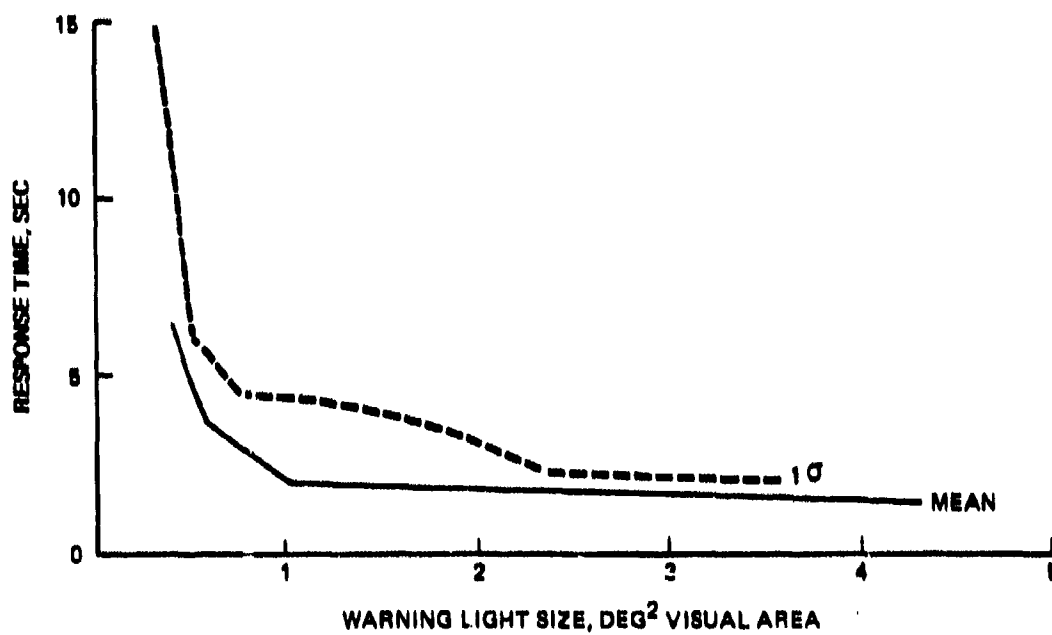
The higher the priority of a signal, the brighter it should be as long as it is not so bright that it blinds the pilot. High-priority signals should be at least twice as bright as other displays in the same area.

Even though the criticality of the signal dictates the intensity of any signal, the range of intensities is dictated by the detection threshold on one end and the disruption of normal activity on the other. Military standards require rear-lighted signals to have a brightness capability of 150 ft-L (dimnable) for high-priority signals and a 15 ft-L (dimnable) for secondary signals. These standards are consistent with research findings. The resulting recommendations were:

- Highest priority signals should be at least twice as bright as secondary displays.
- Lower priority signals should be at least 10% brighter than lesser priority displays in the same vicinity.
- Highest priority signals should have a brightness capability of at least 150 ft-L and secondary signals 15 ft-L.



*Figure 24 Preferred Placement of Visual Signals*



*Figure 25 Effect of Warning Light Size on Reaction Time*

The detectability of flashing and steady lights is dependent upon whether the other possible distracting signals are flashing or steady. The experimental evidence showed that flashing alert lights are detected 30% faster than steady alert lights when combined with steady distractors, but 24% slower than steady lights when combined with flashing distractors. However, the fastest mean detection times are obtained by flashing alerts with steady distracting signals. Therefore it is recommended that high priority alerts should flash and have the capability of making other lights that may be activated go to a steady state.

The effects of color are small as shown in table 17. In most situations, the 0.9 sec (maximum found in the data; in most of the data, the difference is closer to 0.1 sec) in detection time between the most efficient and least efficient colors probably has no practical significance. It was, therefore, recommended to continue using the existing ground rules for colors of alerting lights:

- Red for warning annunciations indicating a hazard that requires immediate action
- Amber for caution annunciations indicating the possible need for future corrective action
- Green for SAFE annunciations

Any other color for lights not described above is acceptable provided the color differs sufficiently from the colors described above to avoid possible confusion.

The auditory stimuli data indicate that the primary factors affecting detection of such signals are:

- Frequency
- Loudness
- Location
- Intermittency
- Message content

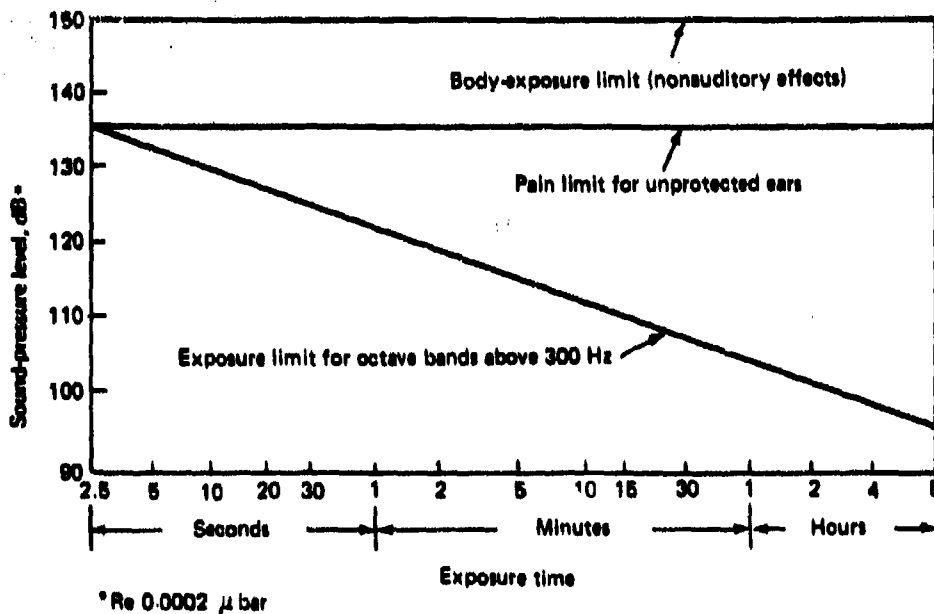
Young humans can detect sounds with frequencies ranging from 20 Hz to about 20,000 Hz. Frequency has a strong effect on perceived loudness. Midfrequency (2000-4000 Hz) sounds tend to sound louder than either high- or low-frequency sounds of the same energy level. Two additional frequency-related factors that impact the detection of aural signals are aging which causes a progressive loss of hearing in the higher frequencies, and ear injuries, which occasionally produce insensitivities or deafness to particular frequencies. For these reasons it is recommended that each aural signal be composed of two or more widely spaced frequencies in the range from 250-4000 Hz.

The guidelines recommended for determining the loudness required of aural alerting signals were expressed as delta loudness required above the masked threshold created by ambient noise. It is important to distinguish between this threshold and ambient noise. "Threshold" is defined as the loudness level required of an aural alerting signal to assure 50% detection. This factor usually has a value that is less than the overall ambient noise level. Methods of calculating this threshold value are presented in reference 2. With cognizance of these factors, the following guidelines for presenting high priority aural alerting signals were derived:

- 15 dB above threshold
- Halfway between threshold and 110 dB

However, these guidelines may in some cases conflict with the pilot criticism that most aural alerts as currently implemented are too loud. Care must be taken when applying these guidelines to the actual cockpit environment because it is possible to introduce sound levels that are intolerable to the pilot. The range of signal intensity by necessity must be limited on one end by the auditory threshold and at the other end by the onset of pain (110 dB). The intensity/exposure time interaction, which imposes limits after which there is a high risk of damage for unprotected ears (figure 26) must also be considered. Thus, until data that resolves this conflict are obtained, it is recommended that the following guideline be used:

$$\text{SIGNAL LOUDNESS} = \left\{ \begin{array}{l} \text{THRESHOLD} + 15 \text{ dB} \\ \text{OR} \\ \text{THRESHOLD} + 1/2 (110 \text{ dB} - \text{THRESHOLD}) \end{array} \right\} \text{WHICHEVER IS LESS}$$



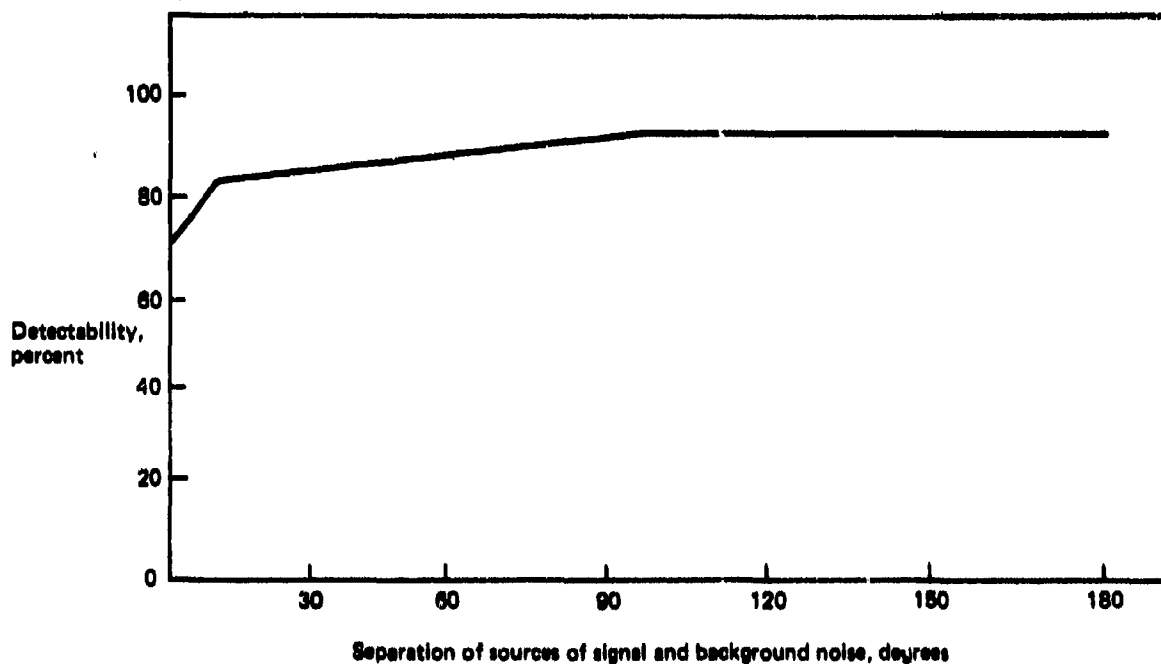
NOTE: PAIN LIMIT FOR UNPROTECTED EARS IS SHOWN AT 110 dB. WHEN EAR PROTECTORS ARE USED, SOUND PRESSURE LEVEL IN SOUND FIELD CAN EXCEED THESE CRITERIA BY AMOUNT OF ATTENUATION PROVIDED BY PROTECTORS. BODY-EXPOSURE LIMIT AT 135 dB IS POINT AT WHICH POTENTIALLY DANGEROUS NON-AUDITORY EFFECTS OCCUR. THIS LEVEL SHOULD NOT BE EXCEEDED IN ANY CASE (ELDRED ET AL' 1956).

Figure 26 Damage Risk Criteria for Various Exposure Times Up to 8 Hours

The experimental data also indicate that aural signals, which are perceived as coming from a different location than the background sounds, are more likely to be detected than signals that cannot be separated in location from background sounds. It was found, as shown in figure 27, that detectability of an aural signal can be improved 40% by going from 0° to 90° directional separation between the sources of background noise and the aural alerting signals. It was also shown that if earphones are used, a substantial improvement in detectability can be obtained by presenting all aural alerting signals only to the pilot's dominant ear. The resulting recommendations from this area of study were:

- Present aural warning signals dichotically to the pilot's dominant ear. (In dichotic listening the alert is presented by an earphone to one ear, and interfering noise or messages are restricted to the other ear.)
- If dichotic separation is not possible, locate the source of aural alerting signals 90° from the source of interfering noise or messages.

Another factor that must be noted is that the human auditory system rapidly becomes used to hearing steady-state signals. Therefore, it is recommended that intermittent sound signals should be utilized for aural alerting.



*Figure 27 Effect of Aural Alerting Signal Source Location*



The detection of a sound signal is often affected by the content of the signal. For example, a person's name is usually more attention attracting than any other auditory message of the same volume. Experimental data indicate that having a person's name precede an auditory message appears to have about the same effect on detection as increasing the loudness of the message by 3 dB. Thus, it is recommended that aural alerting messages can be preceded by an identifier to which the pilot is more than normally sensitive, e.g., the pilot's name or aircraft identification.

Tactile signals consist of such things as vibration, shock, heat, etc. The data indicate that the primary factors affecting the effectiveness of a tactile type signal are intermittency, intensity, and part of body stimulated.

Continuous skin movement is required to stimulate the touch or pressure sense. It has been shown that this sense is maximally sensitive on the fingers at vibrations in the 200- to 3000-Hz range. The intensity of these signals has nominally been given the range of 50-microns. This range is directly related to the area of the body receiving the signal. The sensitivity to touch varies widely from one section of the body to another; the fingers are the most sensitive and the buttocks the least. Therefore, the amplitude of any tactile signal must be calibrated to produce a sensation on the body area where it is placed.

Other types of tactile stimuli should be used very cautiously. They are either dangerous to use, cause excessive startle or adverse reactions, or otherwise inhibit normal pilot actions. The magnitude of an electrical shock, for example, is very difficult to control because of its sensitivity to perspiration. Electrical shock also frequently startles the subject to the extent that he is momentarily incapacitated and then reacts excessively in an inappropriate manner. Other tactile devices such as seatbelt jerkers or seat jabbers tend to inhibit normal pilot movement. These problems are typical of difficulties that are encountered with most tactile stimuli.

Environmental factors such as distractors, existing cognitive workload, and vigilance also have a significant effect on pilot response to a signal. Any kind of distracting stimuli (visual, auditory, or tactile) will have an adverse effect on the detection of alerting signals. In the presence of visual and/or auditory distractors, the effectiveness of types of warning signals from best to poorest are tactile, auditory, and visual. However, tactile distractors have a more disruptive effect than visual or auditory distractors on other activities.

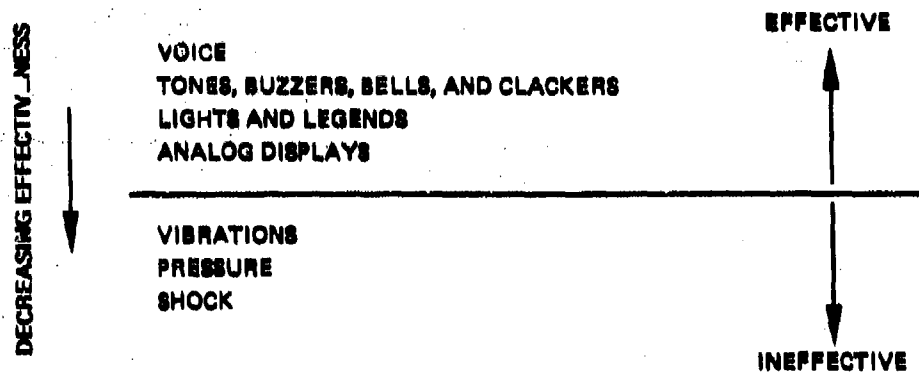
Vigilance and cognitive workloads are a function of the rate at which information is presented. There is a limited range of rates at which human beings process information effectively. When information is presented at rates slower than the optimum rate, an individual will tend not to monitor the information sources effectively and will miss a substantial proportion of the information being presented. Information rates above the optimum range produce cognitive overload. Individuals under a cognitive overload will miss part of the information being presented and will process other parts of the information incorrectly. General characteristics such as these were found in the literature. However, consistent quantitative definitions of the minimum information rate necessary to maintain vigilance and the maximum information rate allowed so as not to cause cognitive overload were not found.

A tabulation was made of response times obtained in the experiments covered by the literature and the conditions under which these times were obtained. This tabulation was used to detect trends and unique characteristics of combinations of stimuli. These data are presented in table 18. From an

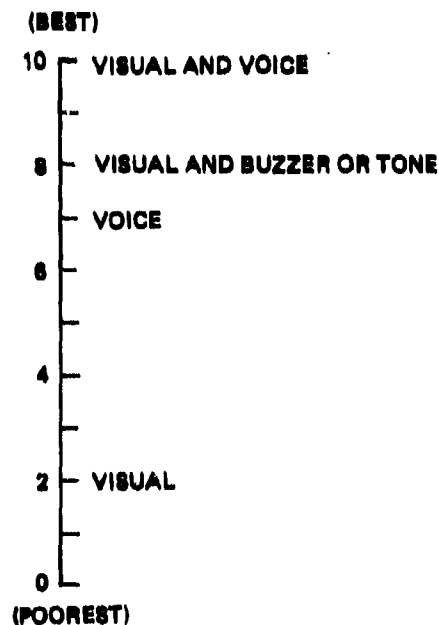
*Table 18 Typical Stimuli Response Times*

NATURE OF STIMULI	RESPONSE TIME, SEC	TEST CONDITIONS
VISUAL	12.12	TRACKING TASK; NO IMPACT ON CONCURRENT TRACKING TASK PERFORMANCE
VISUAL AND BUZZER	4.02	
VISUAL AND VOICE	2.40	
VISUAL AND BUZZER	4.57	TRACKING TASK; BETTER TRACKING WITH VOICE WARNING
VISUAL AND VOICE	1.94	
VISUAL AND TONE	9.35	
VISUAL AND VOICE	7.89	
VISUAL AND BUZZER	2.83	
VISUAL AND VOICE	1.82	
VISUAL	128.27	HIGH-SPEED LOW-LEVEL MILITARY FLIGHT TESTS
VOICE	3.03	
VISUAL	44.05	VISUAL CONSISTED OF ANALOG INSTRUMENTS AND LIGHTS IN AN F-100 AIRCRAFT
VOICE	2.93	
VISUAL (STEADY)	2.0	HUMAN FACTORS TEST IN A STERILE LABORATORY ENVIRONMENT
VISUAL (FLASHING)	1.3	
AUDITORY	2.2	SIMULATION OF A TYPICAL COCKPIT ENVIRONMENT
VISUAL	2.7	
VOICE	1.94	
BUZZER	2.57	
TONE	9.35	F-111 SIMULATOR; EACH ALERT CONSISTED OF A MASTER CAUTION LIGHT, AN ALERT IDENTIFICATION LIGHT, AND AN AURAL ANNUNCIATION OF THE TYPE DESCRIBED TO THE LEFT
VOICE	7.89	
VISUAL	0.494	NO LOADING
AUDITORY	0.453	
TACTILE	0.381	
VISUAL	SLOWEST	NO LOADING EXCEPT VISUAL AND AUDITORY DISTRACTORS
AUDITORY	FASTEST	
TACTILE		

overview of these data, it is obvious that tactile signals produce the fastest response in the non-loaded situation and a combination of visual and aural signals produce the fastest response when used with aircraft-related tasks. Of the combination visual and aural stimuli, the visual/voice combination appears to be more effective than the visual/tone combination. Voice stimuli consistently produce a faster response than visual stimuli. Based on these data, these types of alerting stimuli and combinations thereof might be ranked as shown in figures 28 and 29.



*Figure 28 Alert-Type Effectiveness*



*Figure 29 Relative Effectiveness of Acceptable Types of Alert Stimuli*

#### **2.4.1.2 Time From Detection to Response**

The foregoing discussion has dealt mainly with the detection of signals. However, if an alerting signal is to be effective, the pilot must both detect the alert and make the appropriate response. Therefore, a warning signal must convey information about the nature of the problem and/or tell the pilot how to respond. There will always be a finite interval of time between the detection of the alert and the completion of the response. The length of this interval is primarily dependent on signal-related factors, environmental factors, and previous experience.

The major signal-related factors that affect the time from detection to response are number of steps in the data collection and length of the signal.

A pilot cannot make a correct response to an alerting signal until he has deduced the proper response. If the initial alerting signal contains adequate information, the pilot may initiate action at once. However, if the initial alert does not give adequate information of the nature of the problem, then the pilot must obtain more information before he can take corrective action. Thus, the extra steps in the data acquisition will increase the time to the correct response.

Two experiments were reviewed to obtain a quantified estimate of this effect. In both experiments, alert detection and identification times were measured for visual, buzzer, and voice alerts and combinations thereof. The visual and voice alerts provided enough information so the subjects did not have to scan the other displays to identify the nature of the alert, i.e., a single-step process. The buzzer alerts required the subject to scan one or more visual displays in order to identify the cases, the voice alerts resulted in the shortest identification times. Another advantage of both systems is that under high-stress conditions with peak visual load, this type of system permits the pilot to evaluate the criticality of the problem without adding to his visual workload. It was concluded, therefore, that the number of information-gathering steps required to identify the nature of an alert should be minimized and that voice warnings should be used wherever possible for high-priority alerts. Based on these data and other experiments with voice alerting systems, the recommended practices for voice alerting systems are:

- Reserve voice warnings for highest priority alerting situations.
- Voice alerts, when actuated, should attenuate messages and signals of lower priority.
- Pilots should be familiar with all the messages.
- Messages should be constructed of short sentences of polysyllabic words.

The time from detection to response is also affected by the time required for each step in the data collection. At each step in the data collection, the observer must detect and locate a signal and then process the information in that signal. The time for each step is dependent upon the following factors:

- Time required to process the information in the present step
- Time required to change from one signal source to the next

The time to process the information in any one step is dependent upon the amount of information in that step and the rate at which the information can be assimilated. The rate of data assimilation is directly related to the number of absolutely identifiable signals used for data transmission. The experimental data indicated that the fastest assimilation rates occur with larger signal vocabularies than those currently used for alerts on commercial aircraft. However, this conclusion is valid if, and only if, the signals are not confusable. The inclusion of confusable signals reduced the information assimilation rate and led to errors.

The primary factor affecting the time required to change from one signal to the next is search time, i.e., the number of stimuli the subject must reference to obtain the required information and the data assimilation characteristics of each stimulus. From the experimental data, it was concluded that the longest time required for shifting from one signal to another occurs when the first signal does not give the precise location of the second signal, and the second signal is a visual stimulus.

The environment in which pilots must operate may also affect their alert reaction time. No directly applicable quantified data were available on this effect. However, the experimental evidence does indicate that the response to any stimulus is very much dependent upon the number of possible responses to that stimulus as well as the number of possible responses to all other stimuli. In general, any environmental factor that increases the demands on the pilot will increase the time signal detection to response.

The performance of airplane pilots is strongly affected by skills that they have learned previously in other situations. The effect of a previously learned skill on performance in a new situation is called transfer of training. There are two types of transfer of training—positive transfer and negative transfer. Positive transfer is any improvement in performance due to previous experience and usually occurs when the response to be made in a new situation is similar to the response made in a previous situation. Negative transfer is any detriment in performance due to previous experience and usually occurs when the response to be made in a new situation is different than the response that was made in a previous situation.

The signal-response relationships are often not the same in different aircraft. This may result in negative transfer of the pilot's experience. A study of the effects of negative transfer on crew performance was reviewed in order to assess the significance of this factor. It was found that pilots who are crosstrained to fly several different types of aircraft do make incorrect responses that can be attributed to this negative transfer effect. To minimize this effect, it was concluded that all alerting signals, particularly high-priority alerts, should be standardized on all aircraft.

#### **2.4.2 REQUIREMENTS FOR ADDITIONAL DATA**

In addition to providing data for the formulation of alerting system design guidelines, another major objective of the literature review was to assess the adequacy of the existing data and recommend research efforts necessary to complete the data base. Three tasks were undertaken to accomplish this objective. First the data were evaluated and categorized into two groups, those research efforts directly applicable to the design of alerting systems and those that provided data which, while not quantitatively applicable, provided indications of the direction of the effects. Short abstracts of the data from the studies and military standards that fall into these two categories are tabulated in appendix H. The second task was (1) to delineate those areas where more data are required to provide an adequate data base, and (2) to prioritize those needs so that appropriate research objectives and plans could be formulated in the third task.

### 2.4.2.1 Adequacy of Data in Literature

The data evaluation portion of the review assessed each of the areas of concern listed in table 19. Two aspects of the research data for each area were evaluated to determine their usefulness in developing design requirements. Most important was the relevance of the data to the signal detection and response process. Many of the studies that were evaluated were not applicable even though they dealt with human sensory mechanisms. The remaining data were then reviewed and classified as to the applicability of the quantitative results.

Those data that were obtained in an actual or simulated aircraft cockpit using a flight-type task were considered to be directly applicable. In these studies the observer was required to do a primary task (i.e, tracking a prescribed course or listening to an air traffic controller) and simultaneously respond correctly to any alerting signal. The quantitative results of this type of study closely resembled what may be expected in the "real" flight situation. This class of study included approximately 20% of

*Table 19 Areas of Concern of the Literature Search*

**1. Visual signals**

Size	Location
Brightness	Workload
Contrast	Vigilance
Format	Pilot age
Color	Legend characteristics

**2. Auditory signals**

Frequency	False signals
Intensity	Workload
Ambient noise	Vigilance
Disruptions	Ear dominance
Number of signals	

**3. Bimodal presentation (auditory--visual)**

Interstimulus interval	Workload
Format	Vigilance
Intensity	

**4. Tactile signals**

Detectability	Frequency
Effectiveness	Disruptiveness
Number of signals	
Intensity	

the cited works (see appendix H). The other 80% of the studies were primarily laboratory studies to obtain basic research data. These studies in general used as their unit of measurement the time it takes the observer to react to the signal (reactive time) when that was the only task that he had to do. The quantitative applicability of these types of data to in-flight alerting situations is suspect because of the unrealistic nature of the data-collection process. What can be said is that the time data gathered in these studies is the minimum expected response time for a particular sensory channel and that the highest priority alerts should attempt to produce this time as optimum. Even though the actual quantitative time data from these studies may not be directly relevant to cockpit situations, the information gained about the relationship between variables can be used in many cases.

For example, the real effect of signal location on detection time has not been quantified in the literature for the full range of signals. However, there are simple reaction time data that indicate a trend toward slower reaction as deviation from the line-of-sight increases. These data may be used as an indication of the relative effect of different locations if detection time is a design criteria. Another and possibly more important source of information in these types of data is the number of times the observer missed the signal or gave "no response." These data, although still not directly applicable, quantitatively will come closer to "real world" values because they are not time dependent.

These types of evaluations were made for the data collected in each of the areas of concern. Following this process, it was determined that the amount of directly usable data for all areas of concern was sufficiently low to warrant augmentation. Since the amount of data needed was large, a method of prioritization was needed.

#### 2.4.2.2 Prioritization of Missing Data

Rating, ranking, and paired comparison techniques were used to prioritize the data needs. Two questionnaires were developed using the matrices illustrated in figures 30 through 33. Each questionnaire was distributed to one of two groups of seven people in the Boeing flight deck design organization along with the data that had been gathered and abstracted (see appendix H). The first group of seven were told that "each cell in the matrices (excluding the diagonals) represented a comparison between two variables, i.e., size and location." Their task was to (1) review the data that had been collected, (2) compare the importance of obtaining more data about each variable, and (3) indicate the variable for which more data were most needed by putting its number in the cell. This paired comparison technique allowed the comparison of each variable with every other variable and the ranking of the variables according to their importance.

Another objective of the prioritization scheme was to determine how the variables should be combined in the testing phase to produce the most effective data. To accomplish this objective, a second group of seven raters was told that "each cell in the matrices represented either a single variable (the diagonals) or a combination of two variables, i.e., size and location." They were to assume for the latter case that the combinations of the variables was producing an effect on signal detection and that it was the importance of obtaining additional data on that effect which they were rating. Two variables were used as the maximum number of combined variables because it was felt that the difficulty of rating any more combinations would detract from the usefulness of the findings. The rater's task was to rate the importance of collecting data for each cell on a four-point scale.

	1	2	3	4	5	6	7	8	9	10	11	12
Size												
Brightness												
Contrast												
Location *												
Color												
Workload												
Pilot age												
False signals												
Flash rate												
Frequency of occurrence												
Number of distracting signals												
Signal duration												

• Location with respect to the straightahead

• Highest priority data

• Secondary priority data

• Lowest priority data

Figure 30 Data Collection Priority for Visual Caution and Warning Signals



	1	2	3	4	5	6	7	8	9	10	11	12
Intensity												
Frequency (pitch)												
Types of background noise												
Workload												
Pilot age												
False signals												
Number of different signals												
Frequency of occurrence												
Location *												
Signal-to-noise intensity ratio												
Signal duration												

• Spatial location of the sound or one- vs two-ear presentation  
 \* Highest priority data      ☆ Secondary priority data      ■ Lowest priority data

Figure 31 Data Collection Priority for Nonverbal Auditory Caution and Warning Signals

	1	2	3	4	5	6	7	8	9	10	11
Intensity											
Types of background noise											
Signal-to-noise intensity ratio											
Number of distracting messages											
Message content											
Voice type *											
Familiarity with messages											
Intelligibility of speech											
Pilot age											
Workload											
False signals											

\* Voice differences may occur in such things as: male, female, pitch, stress, intonation, etc.

☼ Highest priority data

★ Secondary priority data

■ Lowest priority data

Figure 32 Data Collection Priority for Verbal Auditory Caution and Warning Signals

1	2	3	4	5	6	7	8
Modal priority *	Signal duration	Interstimulus interval **	Differential signal intensity	False signals	Pilot age	Workload	
1	★	★	★	★	★	★	★
2	★	★	★	★	★	★	★
3	★	★	★	★	★	★	★
4	★	★	★	★	★	★	★
5	★	★	★	★	★	★	★
6	★	★	★	★	★	★	★
7	★	★	★	★	★	★	★
8	★	★	★	★	★	★	★

\* Which signal (auditory or visual) should be presented first?

\*\* How much time should be given between the two signals?

\*\*\* Spatial location of each of the signals

★ Highest priority data

☆ Secondary priority data

■ Lowest priority data

Figure 33 Data Collection for Binodal (Auditory-Visual) Caution and Warning Signals

The results from the two sets of matrices were combined to form the prioritization that can also be seen in figures 30 through 33. The diagonal priorities represent the importance of individual variables and the other cell priorities the importance of the two variable interactions. To assess the validity of the responses, two variables—visual signal size and aural intensity—were included even though they were covered by directly applicable data in the literature review. Both of these variables were low priority in the survey.

#### 2.4.2.3 Test Plans for Acquiring Missing Data

The high-priority data requirements established in figures 30 through 33 were evaluated and a set of 19 three-page test plans was constructed. The groundrules followed for the first cut at defining required test programs were:

- Use as many of the high-priority data cells as possible.
- The number of variables and levels should be chosen to provide approximately 2 weeks of testing per test plan.
- The test design should be statistically sound.

The resulting test designs are presented in appendix I. It should be noted that if the time restraints (2 weeks testing per test plan) are relaxed, some of the test plans can be expanded quite easily to include a larger number of variables.

These test plans define only the testing necessary to fill the most important gaps in the human factors data required to design alerting systems. Elements of alerting systems will be evaluated by these tests. Then alerting system concepts based on substantiated design data can be developed. Another set of tests that provide comparative evaluations of these concepts are then required in order to validate the ideas incorporated therein. The exact nature of these comparative tests has not been defined yet.

### 2.5 PRELIMINARY RECOMMENDATIONS FOR STANDARDIZATION OF ALERTING METHODS AND FUNCTIONS

Current alerting methods and the inconsistencies in the alerting philosophies applied thereto were reviewed in section 2.1. Alerting function and system requirements were established in section 2.2. The rationale, criteria, and method for prioritizing the alerting functions were developed in section 2.3. A review of the human factors data applicable to designing alerting systems was presented in section 2.4. These four aspects of developing alerting systems were combined to formulate *preliminary recommendations* for standardizing alerting methods and functions. The recommendations, a sample alerting system concept that conforms with these recommendations, and an analysis of the conflicts between the proposed prioritized alerting systems, tradition and existing requirements are presented in this section.

## 2.5.1 RECOMMENDED DESIGN GUIDELINES

The recommendations presented in this section should *not* be interpreted as firm design guidelines or as minimum performance standards. At this time, these guidelines have been only partially substantiated. Significant testing is still required to validate these guidelines.

The interactions between the data presented in the previous sections were analyzed, agreements, correlation and conflicts were noted, and preliminary design guidelines (not minimum performance standards) for alerting systems were formulated.

The design guidelines were oriented to provide the following type of alerting system characteristics and cockpit environment:

- A consistent design philosophy that can be applied to all new aircraft, irrespective of manufacturer.
- Quiet, dark cockpit when all systems are operating normally and when abnormal situations have been "cleaned-up" (except automatic flight control mode annunciators).
- Associate a unique audio, visual, or combination audio-visual method of alerting with each alert priority level.
- Provide alerting system growth capability in a form that does not necessitate additional discrete annunciators.

Accordingly, the following preliminary design guidelines are recommended.

### Prioritization

- Selected alerts should be categorized as a function of criticality and flight phase. Category criteria are presented in table 14. Flight phases that might be considered are defined in table 15.
- Selected alerts within each category should also be prioritized as a function of criticality.

### Inhibits

- The number and type of alerts that can be annunciated during critical phases of flight should be restricted.
- Prioritization of the alerts may be used as a method of inhibiting or at least attenuating non-essential alerts.

## Visual Alerts

- An alphanumeric readout device, located in front of each pilot, should be provided to identify warning- and caution-type alerts.
- Discrete alerts—Wherever possible, reduce the number of annunciations in the cockpit.
  - Advisory lights should not illuminate unless a discrete crew action, such as pushing a button, is performed (except automatic flight control mode annunciators).
- Red alerts—Apply only to situations where immediate action is required, i.e., only LEVEL 1 alerts.
  - Use when annunciation by an aural alert plus the alphanumeric readout devices is not adequate.
- Amber/yellow alerts—Apply only to situations that require immediate crew awareness and eventual action, i.e., only to LEVEL 2 alerts.
  - Use when annunciation by the common aural alert for all LEVEL 2 items and the alphanumeric readout devices is not adequate.
- Green alerts—Use to confirm the SAFE OPERATION or GO status of a system.
  - A manual action by the crew, such as pushing a button, should be required to illuminate green lights (except automatic flight mode annunciators).
- Blue alerts—Use to annunciate intransit conditions.
  - A manual action by the crew, such as pushing a button, should be required to illuminate blue lights (except automatic flight mode annunciators).
- White alerts—Use for illuminating keyboards and annunciating ON/OFF system modes, i.e., when used in place of toggle switches.
- Location—LEVEL 1 alerting devices (warnings) should be located within  $15^{\circ}$  of the pilot's centerline of vision (centerline of vision is defined as the line between the pilot's eye reference point and the center of the ADI).
  - LEVEL 2 alerting devices (cautions) should be located within  $30^{\circ}$  of the pilot's centerline of vision.
  - Green, blue, and white lights can be located anywhere in the cockpit that is readily visible to the crew.
  - All alerts presented by discrete lights, flags, or bands should be repeated on the alphanumeric readout device (except automatic flight mode annunciators).

- **Size**—High priority lights (associated with LEVEL 1 and 2 alerts) should be no less than 1° visual angle in size.
  - Secondary lights (associated with LEVEL 3 and lower priority alerts) should be no less than 0.5° visual angle in size.
- **Brightness**—LEVEL 1 alerts should have a brightness capability of at least 150 ft-L and should be at least twice as bright as other displays in the vicinity of the alert.
  - LEVEL 3 and lower priority alerts should have a brightness capability of at least 15 ft-L and should be at least 10% brighter than nonalert displays in the vicinity of the alert.
  - Automatic brightness adjustment for varying ambient light conditions should be provided.
- **Flashing**—Use only for highest priority (LEVEL 1) alerts.

#### **Aural Alerts**

- **Application**—Use discrete aural alerts to annunciate highest priority situations (LEVEL 1 alerts) and to attract attention to LEVEL 2 alerts on the alphanumeric readout device.
- **Maximum number**—Less than four familiar alerts (based on pilot opinion).
  - If the number of discrete aural and tactile alerts exceeds seven, they should be supplemented by voice annunciations.
- **Intensity**—Should be less than intensity of most currently used aural alerts.
  - Maximum intensity of 15 dB above threshold noise level or halfway between threshold level and 110 dB, whichever is less.
  - Automatic intensity adjustment for varying ambient noise conditions should be provided.
  - Aural alerts associated with LEVEL 1 items should be noncancellable without correction of the fault or situation.
  - A means of reducing the annoyance of continuous aural alerts after initial recognition is achieved should be provided.
  - A means of disabling any nuisance actuation of an aural alert should be provided in a form that does not affect the integrity of the other aural alerts (e.g., one circuit breaker or guarded/wired shutoff switch for each aural alert).

- Sound characteristics—Each signal should be composed of two or more widely separated frequencies in the range from 250-4000 Hz.
  - Intermittent signals should be used.
- Voice characteristics—Messages should be preceded by an identifier to which the pilot is more than normally sensitive (attention getter).
  - Messages should be constructed of short sentences of polysyllabic words.
  - Pilots should be familiar with all voice messages.
- Location—Aural alerts should appear to emanate from the vicinity of the alphanumeric readout device.

#### **Tactile Alerts**

- Minimize use of tactile alerts.

#### **Master Warning/Master Caution**

- A master warning signal and a master caution signal should be located in front of each pilot if the alphanumeric readout display is located outside the pilot's primary field of view.
- All LEVEL 1 alerts should activate the master warning signal (if utilized).
- All LEVEL 2 alerts should activate the master caution signal (if utilized).
- No LEVEL 3 or 4 alerts should activate the master warning or master caution signals (if utilized).

#### **Checklists**

- Type of alert and type of checklist used to rectify an annunciated situation should correlate.
- Emergency procedures should be associated only with LEVEL 1 (warning type) alerts.
- Abnormal procedures should be associated only with LEVEL 2 (caution type) alerts.

NOTE: A checklist is not necessarily associated with each LEVEL 1 or LEVEL 2 item, and an alert is not necessarily associated with each checklist.

### **2.5.2 SAMPLE ALERTING SYSTEM CONCEPT THAT CONFORMS WITH RECOMMENDED DESIGN GUIDELINES**

One of the primary goals of this study is to provide preliminary design guidelines for achieving a quiet, dark cockpit when all systems are operating normally and when abnormal situations have been "cleaned-up." With the quiet, dark cockpit concept, all visual and auditory alerting devices except



automatic flight mode annunciators would be OFF unless (1) an abnormal situation exists or (2) the crew desires annunciation of a specific situation. The amount of advisory and status information in the cockpit would be minimized. The crew would have the capability to enable or disable certain annunciations, primarily status information. Manual action by the crew would be required to get a momentary display of certain annunciations, e.g., the annunciation of intransit conditions. The crew would then have a "clean" cockpit to work in, would not become insensitive to common annunciations, and would recognize and be able to correct abnormal situations more rapidly than in current cockpits.

The recommended preliminary design guidelines could be applied as follows to fulfill this objective. Discrete aural alerts were recommended for annunciating LEVEL 1 situations, for attracting attention to the alphanumeric display when LEVEL 2 situations arise, for annunciating assigned altitude deviations and decision height, and possibly for annunciating incoming communications. Accordingly, a unique discrete aural alert might be required for each of the following situations:

- Gear down and locked but lever not in down detent
- Unsafe takeoff configuration
- Unsafe landing configuration
- Ground proximity warning
- Rapid depressurization
- Autopilot disconnect
- Common attention-getting tone for all LEVEL 2 alerts
- SELCAL
- Cabin call
- Data link
- Decision height
- Altitude alert (altitude deviations)

Thus 12 discrete aural alerts would be required; however, another guideline stated that the number of aural alerts should not exceed 4 (pilot opinion). The number of discrete aural alerts can be reduced almost to this number by retaining the traditional horn for all LEVEL 1 "unsafe configuration" warnings; by incorporating the alerts for SELCAL, cabin call, and data link into the integrated alerting system as LEVEL 2 alerts; and by using a command aural alert for decision height and altitude deviations. One aural alert could be used for unsafe takeoff configuration, unsafe landing configuration, and gear down and locked but lever not in down detent.

The central alphanumeric readout device could simultaneously denote the exact nature of the configuration problem. Similarly, the common tone used for all LEVEL 2 alerts could be used for

annunciating incoming SELCAL, cabin call, and data link messages, and the alphanumeric readout device could denote the specific communication channel requiring attention. Decision height could not be included as a LEVEL 2 alert because the pilot cannot afford to divert his attention to reading the alphanumeric display at the critical time when this is annunciated. Thus decision height and altitude alert require a separate, distinct aural alert. By implementing the system in this manner, the number of aural and tactile alerts would be reduced to six.

The number of potentially ambiguous aural alerts could be even further reduced by using voice annunciations for all other LEVEL 1 alert situations listed above. However, the effects of extensive application of voice alert annunciations are not known at this point. Current experience with voice alerting systems has not been satisfactory. The type of systems described above wherein a small number of discrete aural alerts are used in conjunction with an alphanumeric display is thus recommended at this time.

In addition to these types of annunciation for the high-priority alerts, a very limited number of green, blue, and white advisory alerts would be utilized. A third switch state might be added to the lights test switch to handle these alerting functions. The three lights test switch positions would be reassigned to provide the following functions:

- **TEST**—All lights ON to test light sources plus test pattern on alphanumeric display to validate operation of display.
- **IMMEDIATE SITUATION**—All faults, intransit conditions, etc., would be annunciated as they occur. Existing alert situations would also be annunciated. Alerting system operation would be as in current aircraft.
- **CLEAR**—This would cancel all currently displayed alerts except warnings and automatic flight mode annunciations and provide a relatively quiet, dark cockpit. No intransit or SAFE/GO conditions would be automatically annunciated while the system is in this state. Only new cautions and warnings would be automatically annunciated. Any new caution annunciation could be "cleared" by switching from CLEAR to IMMEDIATE SITUATION and back to CLEAR. A small pushbutton might be added to each system's panel. While in this alerting system operating mode, the crew could get all green, blue, and white light annunciations on that system panel by pushing this button. This would provide the crew with selective alert annunciation capability.

These alerting system implementation ideas are at this point only preliminary suggestions and examples of how the design guidelines could be applied to (1) clean up the cockpit, (2) provide the crew with the capability to select an alerting system operating mode that is similar to current aircraft, and (3) provide the crew with the capability to select an alerting system operating mode that results in a relatively quiet, dark cockpit when all systems are operating normally and when abnormal situations have been "cleaned up." These ideas represent only several of many ways in which an alerting system could be implemented and still conform to the recommended design guidelines. More refinement, testing, and analysis of the hardware/implementation impact of these concepts are required to validate them.

### 2.5.3 CONFLICTS BETWEEN TRADITION, REQUIREMENTS, AND RECOMMENDED DESIGN GUIDELINES

The preliminary design guidelines recommended in section 2.5.1 conflict with traditional alerting system concepts and with the requirements in the following areas:

- Elimination of traditional aural
- Downgrading of several alerts previously considered high-priority items
- Terminology used in the FARs

The priority system proposed in table 16 conflicts with tradition by eliminating several traditional aural alerts. This priority system would eliminate the unique aural alerts associated with fire, excessive airspeed, stabilizer in motion, and below glide slope warnings. Many pilots feel that these aural alerts are sacrosanct. However, the analyses showed that the required pilot response to these alerts is not immediate action. Thus, they do not qualify as LEVEL 1 alerts and do not deserve unique discrete aural.

The proposed priority system also conflicts with tradition by downgrading several alerts previously considered high-priority alerts from red lights to amber lights or no lights at all (just an alphanumeric identification). In the case of the 737, autopilot disconnect, fire, gear unlocked, and gear not down and locked with thrust lever at idle are examples of traditionally large, red light alerting functions that might be downgraded. The amber flight director mode "armed" annunciations are examples of alerting functions that might be downgraded or modified so as not to imply a "caution" situation. Similarly, other functions might be upgraded. The blue lights used to annunciate APU oil quantity low and thrust reverser armed are examples of such alerts. In a new aircraft, these alerts might be upgraded to amber lights and green lights, respectively, so as to make the color of the light reflect the criticality of the situation.

Federal Aviation Regulations (FARs) use the word "warning" indiscriminately. Examples of where such usage occurs in the FARs are tabulated in table 20. If the guidelines recommended herein are adopted, the language in these FARs will have to be modified. It is suggested that the type of terminology used in other sections of these FARs to indicate a requirement for an alert be extended to all FARs and that the term "warning" be deleted. Examples of such terminology are the following:

- "Means to indicate"
- "An aural or visual signal"
- "Means must be provided to alert the crew"

**Table 20 Federal Aviation Regulations Using the Term "Warning"**

25.207(b)  
25.729(e)(2), (3) and (4)  
25.777(c)  
25.812(e)(2)  
25.841(b)(6) and (7)  
25.859(e)(3)  
25.1165(g)  
25.1203(b)(3)  
25.1303(c)(1)  
25.1305  
25.1309(c)  
25.1353(c)(5)(ii) and (iii)  
37.201(a)(3)  
91.49  
121.289(a) and (b)  
121.360(b) and (c)

### 3.0 CONCLUSIONS

The alerting system implementation guidelines specified herein should be interpreted as (1) *preliminary*, not final, design guidelines, and (2) design objectives, not minimum performance standards. The recommended design guidelines are only partially substantiated by quantitative data—they represent our best implementation ideas at this time. Additional testing to (1) derive directly applicable human factors data, (2) quantify the effectiveness of various elements of alerting systems, and (3) quantify the effectiveness of various full alerting system concepts plus an analysis of the hardware/implementation impact of these concepts are required to complete and validate the proposed design guidelines.

The following conclusions are the results of analyses of current alerting methods and requirements, the development of alert prioritization criteria, and a survey of human factors data pertinent to the design of alerting systems.

The aircraft operators and manufacturers apparently feel the pilots need more in-flight malfunction resolution capability and need to record better maintenance data. Thus each new aircraft has incorporated more alerting functions specifically due to a trend toward providing the crew with more detailed subsystem information. The most rapid growth in the number of subsystem alerts has occurred in the electrical, navigation, and automatic flight control systems. Negligible growth has occurred in the air-conditioning, altitude alert, APU, communications, emergency equipment, flight instrument, air data, fuel, and powerplant systems. All other systems have exhibited moderate growth in the number of alerts. With this proliferation of alerts, the cockpits have become saturated with information systems. More multifunctioning of the alerts is being used to get around the lack of panel space problem. The inclusion of these devices is adding to the potential for confusion in the cockpit.

The number of alerts, especially the number of aural alerts, should be reduced. The potential for confusion exists with this many alerts. To maximize the effectiveness of the alerts, noncritical alerts should be inhibited during high workload periods such as takeoff and flare/landing. Prioritization of the alerts, so as to identify the most critical problem, should also be considered.

Prioritization of the alerting functions currently must be accomplished via subjective methods. Numerical methods require additional quantitative data about crew reliability and pilot latency, and the effects of workload on these two factors, or the time history of the aircraft's/system's performance degradation as related to each alert.

Criteria for four levels of alerting function prioritization are available. Most organizations working toward developing standards for alerting systems basically agree with the four levels of priority established in this study and the criteria defining these levels. Minor grammatical differences remain to be "ironed out."

Standardization of the alerting function priorities may be possible for alerts within the two highest priority levels. However, the alerts within the two lowest priority levels are too dependent on each aircraft's unique design features to be amenable to priority standardization.

A unique audio, visual, or combination audio-visual method of alerting should be associated with each priority category to provide an instantaneous assessment of the alerting situation's criticality. Human factors data pertinent to optimizing this audio-visual interface with the pilot are available. However, the data are incomplete and further testing of specific elements of alerting systems is required to fill the major data gaps.

Preliminary design guidelines for standardization of alerting functions and methods are available. The basic guidelines specified in section 2.5.1 are recommended. Numerous conflicts exist between these guidelines, traditional alerting system concepts, and existing regulations. Most conflicts with existing regulations can be resolved with minor modifications of the language used to indicate a requirement for an alert.

Additional comparative testing of elements of alerting systems and full alerting system concepts plus analyses of the hardware implementation characteristics of these concepts are required to complete and validate the proposed design guidelines.

## APPENDIX A

### TABULATION OF ALERTING FUNCTIONS AND IMPLEMENTATION CHARACTERISTICS

This appendix provides detailed descriptions of the alerting functions in a typical configuration of each basic type of commercial turbojet transport aircraft. To simplify this tabulation, similar types of indications were consolidated under one title. Examples are: (1) red bands, red limit marks, and pink limit marks were consolidated under the title "red bands" because they have similar operational implications; (2) fire orange flags used as warning indications were tabulated as red flags; and (3) yellow lights were tabulated as amber lights.

The asterisks on tables contained in this section mean "same as."

Air conditioning (Sheet 1)

Alerting function	Type of alert							Applicable federal aviation regulations (FAR)
	701/720	721	737	747	DC-8	DC-9	DC-10	L-1011
1 Air conditioning system malfunction			1 awh it					1 awh it
2 Air supply temp high						2 awh it		
3 Automatic cooling air valve open								
4 Automatic vent duct air flow sensor or flow restricted								2 awh it
5 No air flow in ducting or export cooling temp	1 awh it	2 awh it	1 awh it	1 awh it			1 awh it	2 awh it
6 Cargo heat on				1 awh it				
7 Cargo compartment too hot or too cold				1 awh it				
8 Center accessory compartment overheat				1 awh it	1 awh it (+ 15)			0 awh it
9 Cool air mod valve closed (valve & indicator visible)							1 awh it	
10 Differential pressure increase								
11 Duct overheat	2 awh it	3 awh it	2 awh it	5 awh it (+ 10)		1 awh it		1 awh it
12 Equipment cooling valve position (open)	1 awh it						1 awh it (+ 15)	1 awh it
13 Floor heat failed								
14 Floor heat off								1 awh it
15 Forward cabin compartment overheat								
16 Forward pack on	2 awh it			1 awh it (+ 7)			1 awh it (+ 11)	2 awh it
17 Forward system compressor off	2 awh it			2 awh it				
18 Cabin compressor overheat								
19 Forward compressor overheat				4 awh it				
20 Abnormal frost temperature				2 awh it				
21 Humidity control outside				0 awh it				1 awh it



	Alerting functions	Type of alert										Applicable Federal aviation regulations (FAR)
		707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111		
22	HEE flow off								2 amb its			
23	OVV schedule descent			1 amb its								
24	Outflow valve opening mode manual (auto full)				1 amb its				2 amb its			
25	Outflow valve inactive			1 its its					2 gen handle			
26	Pack control mode (auto/manual)								8 amb its			
27	Pack trip, valve & door indicators mode				3 variable dual legend its							
28	Pack area overheat								3 amb its			
29	Pack overheat trip off		2 amb its (+ 31)	2 amb its	3 amb its	4 amb its		3 amb its	3 amb its	2 amb its	25.800(d) (3) There must be means to warn the crew when any lower volume heat signal is cancelled for safe operation has been shut off by the automatic means prescribed in subparagraph (1) of this paragraph.	
30	Auto pack trip armed		1 gen its									
31	Pack valve closed		2 amb its (+ 25)									
32	Pressurization failure	intermittent buzz	intermittent buzz	1 amb its & intermittent buzz	intermittent buzz		1 and its & buzz	2 and its & buzz	1 amb its & intermittent buzz	1 and its	25.800(b) Pressurization cabin must have at least the following warning, control, and indicators for control of cabin pressure: (a) Warning indicators at the pilot or flight or crew station to indicate when the safe or pre-set pressure differential and therefore cabin pressure limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator must be the existing requirements for pressure differential limits and manual or visual signal for addition to cabin altitude indicating means must be the existing requirements for standby cabin pressure limits if it is the flight crew when the cabin altitude pressure is below that equivalent to 10,000 feet. (1) A warning placed at the pilot or flight crew station if the maximum is not designed for pressure differential up to the maximum relief valve setting in accordance with paragraph (b).	
33	Pressurization system operating mode			2 gen its					1 its its			
34	Standby pressurization system operating mode							1 its its				
35	Pressure safety valve open								2 amb its			
36	Radio rack fan off						1 amb its			1 amb its		

Not continuing (Sheet 2)

Applicable Federal aviation regulations (FAR)									
Alerting function	Type of alert								BAC-111
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	
Run air door open		2 sds ltr						1 sds ltr	
Run air door operating unsatisfactorily									
Peak discharge temp high							1 system ltr		
Oilval valve open				2 sds ltr			1 sds ltr		
Smoke in equipment cooling compartment				1 sds ltr					
Tail compartment temp high						1 sds ltr			
Temperature indicator needs attention				3 sds ltr and 1 sds ltr				2 sds ltr	
Temperature regulator fault	2 sds ltr								
Tire air press hi				1 sds ltr			1 sds ltr		
Turbine inlet temp hi							1 system ltr		
Water regulator and/or system - manual control		2 sds ltr							
Zero condition	1 sds ltr					1 sds ltr			
Zero when valve closed				5 sds ltr (*11)				5 sds ltr	
Fumes regulator					4 sds ltr				

Alerting function	Type of alert							Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	L-1011	BAC-111
1 Position lights on							1 each ft	
2 Strobe lights off							1 each ft	
3 Anti-collision lights off							1 each ft	
4 Wing flood lights on							1 each ft	
5 Wheel well lights on							1 each ft	
6 Forward mast lights on				1 each ft in 8 hour			1 each ft	
7 No parking light on				1 each ft in 8 hour			1 each ft	
8 Thunderstorm lights on							1 each ft	
9 Eye locator light on							1 each ft	
10 Pilot's warning, caution advisory lights intensity bright dim						1 each ft	2 each ft	
11 Pilot's warning, caution & advisory light test mode						1 each ft	1 each ft	
12 Flight engineer's warning, caution & advisory lights intensity bright/dim							2 each ft	
13 Flight engineer's warning, caution & advisory light test mode							1 each ft	
14 Master caution			2 each ft			2 each ft		
15 Master warning	1 ft red ft	1 ft red ft			1 each ft	2 each ft		2 ft red ft
16 Flight recorder off		1 each ft	1 each ft	1 each ft	1 each ft	1 each ft	1 each ft	
17 Cockpit voice recorder test ok								
18 Master projection on				3 ft red ft			2 each ft	

25.771(d) If provision is made for a second pilot, the system must be controllable with equal safety from either pilot seat. 25.777(h) Each cockpit control must be designed to provide consistent operation and to prevent confusion and inadvertent operation. 25.1309(c) Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated warning and warning means must be designed so that crew errors that would create additional hazards are improbable.

25.1409(d) Each flight recorder required by the operating rules of this chapter must be installed in that—(4) There is no need or usual reason for preflight checking of the recorder for proper recorder tape movement.

25.1409(h) Each cockpit voice recorder must be installed in that—(3) There is no need or usual reason for preflight checking of the recorder for proper operation.

Aircraft manual (Sheet 2)

Alerting function	Type of alert									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
21 Master projector off								1 red ft		25.1322 If warning, caution or advisory lights are installed in the cockpit, they must, unless otherwise approved by the Administrator, be—(a) Red, for warning lights; (b) Amber, for caution lights; and (c) White, for advisory lights. (d) Any other color, including white, for lights not described in paragraphs (a) through (c) of this section, provided the color differs significantly from the colors prescribed in paragraphs (a) through (c) of this section to avoid possible confusion.
25 Water system pressure limit								1 white/red band		
27 Flt deck door lock released			1 red ft	1 blue/red ft						
30 Aft service hatch doors		1 grn ft								
31 Galley fault								1 red ft		
32 Diffraction illumination on overhead panel			1 red ft							
33 Water fire heater failure										
34 Door fault/open	8 red ft	13 red ft	9 red ft	10 red ft	2 red ft	7 red ft	20 red ft	12 red ft & 11 red ft	5 red ft	
35 General requirement										

## Methods and systems

Alerting functions	Type of alert									Applicable Federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
Approaching altitude	1 aural & C cleared	1 aural & tone	1 aural & tone	1 aural & tone	2 aural, tone & flag (1" x 3)	1 aural & tone	1 aural & tone (1" x 3)	2 aural & tone	Tone	91.1304 Each altitude alerting system or device required by paragraph (b) of this section must provide (a) alert the pilot, upon approaching a published altitude in either ascent or descent, by a sequence of both aural and visual signals in sufficient time to establish level flight at that published altitude; (b) be tested without special equipment to determine proper operation of the alerting system; (c) be tested before 1,000 feet AGL; the system or device need only provide one signal, either aural or visual, to comply with this paragraph.
On-altitude	1 aural	1 aural		1 aural		1 aural		2 aural		
Altitude deviation	1 aural	1 aural		1 aural & flag (1" x 1)	2 aural, tone & flag (1" x 1)	1 aural & tone	1 aural & tone (1" x 1)	2 aural & tone		
Altitude alert failure	1 aural & backup panel flag	1 aural & backup panel flag	1 aural flag		1 aural flag	1 aural flag		1 aural flag		

APU (cont. 1)

Alerting function	Type of alert								Applicable Federal aviation regulations (FAR)
	703/720	723	733	747	DC-8	DC-9	DC-10	L-1011	
APU RT overtemp/low shutdown								1 red flag	
APU low oil pressure/low shutdown			1琥珀色					1 red flag	
APU high oil temp/low shutdown								1 red flag	
APU failure gas temp overtemp/low shutdown								1 red flag	
APU don't load alert								1琥珀色	
APU compartment vent closed								1琥珀色	
APU inlet flow restriction/low shutdown								1琥珀色	
APU oil quantity low			1琥珀色					1琥珀色	
APU battery shorted or overboard								1琥珀色	
APU flame-in-leak								1琥珀色	
APU fuel filter clogged or icing								1琥珀色	
APU over temp (excess air flow)								1琥珀色	
APU over temp shutdown system alarm								1琥珀色	
APU bleed air valve open								1琥珀色	1 ( 30
APU start switch on		1琥珀色						1琥珀色	
APU EGT overtemp		1琥珀色/琥珀色	1琥珀色/琥珀色			1琥珀色/琥珀色	1琥珀色		
APU overtemp—normal & overtemp range						1琥珀色/琥珀色			
APU oil temp hi			1琥珀色			1琥珀色	1琥珀色		
APU oil pump low						1琥珀色	1琥珀色		
APU fuel valve in-leak				1琥珀色					
APU DC fuel pump on				1琥珀色					

APC Sheet 2

Alerting function	Type of alert								Applicable Federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	
APV failure			1 each ft	1 each ft					
APV inlet door in transit				1 each ft					
APV fuel valve not closed		1 each ft							
APV over-heat			1 each ft				2 electrical one fusible		
APV fuel pressure low							1 each ft	1 each ft	
APV fuel pump switch on							1 each ft		
APV door open							1 each ft		
APV operating in standby control mode using electrical power							1 each ft		
APV fuel valve open								1 ft	1 ft

Automatic flight control system (Aircraft 8)

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	700/726	727	737	747	DC-8	DC-9	BC-18	L-1011	
Autopilot/flight director cut, 1 approach mode armed								1 sub it	
Flight director altitude hold mode armed				2 sub it (* 10)				2 sub it (* 11)	
Flight director selected altitude capture				2 sub it (* 9)				2 sub it (* 12)	
Autopilot altitude hold mode armed				2 sub it (* 12)				2 sub it (* 5)	
Autopilot selected altitude capture				2 sub it (* 11)				2 sub it (* 10)	
Flight director approach speed command mode armed				2 sub it (* 17)					
Flight director approach speed command capture				2 sub it (* 16)					
Autopilot disconnect	2 sub it	2 sub it	2 sub it	2 sub it (* 21, 50, 50, 57) & WINGLOCK	2 sub it	1 sub it & click	2 sub it & 102	2 sub it & 102	1 sub it
Improper AFCS configuration for selected mode								Indicated by 20, 21, 102, 105, 106	
Autopilot failure during selected approach								2 sub it (* 21)	
Marginal AFCS condition for selected operation				2 sub it (* 10, 50, 50, 57)				2 sub it (* 20)	
Autopilot's controller created at fault								2 sub it	
AFCS failure—master warning signal								2 sub it	
Autopilot disconnect	1 sub it	1 sub it	2 sub it (Range)	2 sub it (* 50, 57)		1 sub it	2 sub it & 102	2 sub it	
Autopilot channel failure								2 sub it	
Go-around comparison failure								2 sub it	
27.1104b (2) Additions. In addition to the items of indication specified in section 27.1104b, the following shall be included: (a) "Fuel", sufficient indication. There shall be provided to indicate readily to the pilot in a positive manner when each phase of the primary power levers is not armed to the automatic pilot is not adequate for takeoff. (b) "Autopilot" indication to indicate readily to the pilot in a positive manner when the automatic pilot is not engaged to the selected navigation reference.									

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(1) Addition. In addition to the means of indication specified in section 8.3 of FAR 105A, the following shall be included: (a) Flare, indication indication. Means shall be provided to indicate readily to the pilot in a positive manner when each phase of the primary power (engine) failure control in the automatic pilot is not adequate for safe operation. (b) Autopilot navigation indication. A visual means shall be provided to indicate readily to the pilot in a positive manner when the automatic pilot is not capable of the address navigation indication.



Automatic flight control system (Sheet 2)

Alerting function	Type of alert									Applicable Federal aviation regulations (FAR)
	701/720	727	737	747	8C-8	8C-9	DC-10	1-1011	BAC-111	
27 Fuel compression failure								2 solid flag		
28 Autopilot tripped from command to CRS because of faulty inputs								2 solid flag		
43 Autopilot landing mode armed								2 solid flag		
44 Recovery slope mode of autopilot armed								2 solid flag		
45 Flare mode of autopilot armed				4 solid flag fl				2 solid flag		
46 Flight director in manual mode								2 solid flag		
47 B-bar mode engaged								2 solid flag		
52 AFCS mode selector not locked							2 solid flr			
53 Autopilot roll not locked on				2 red flr (+20, 54)						
54 Speed error more than 10 knots				2 solid flr (+20, 53)						
55 Autopilot bank without clearance				2 red flr (+10, 21, 55 & 57)						
56 Autopilot roll not locked on				2 red flr (+10, 21, 55 & 57)						
57 Autopilot channel not in agreement while in auto-land mode				2 red flr (+10, 21, 55 & 57)						
58 Flight director on				2 green flr						
59 Flight director VWS/LBC capture mode armed			2 solid flr (+03)	2 solid flr (+03)						
61 Flight director VWS capture/LBC capture			2 green flr (+00)	2 green flr (+00)						
62 Flight director glide slope capture mode armed			2 solid flr (+03)	2 solid flr (+03)				2 solid flag (+00)	2 ( 3 flag	
63 Flight director glide slope capture			2 green flr (+02)	2 green flr (+02)				2 solid flag (+02)	2 ( 3 flag	
66 Autopilot VWS/LBC capture mode armed	1 solid flr (+05)	1 solid flr (+05)	2 solid flr (+05)	2 solid flr (+05)						

Automatic flight control system (Scheme 2)

	Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
		707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	RAC-119
66	Asymptotic VOR course/ LOC capture	1 gm ft (= 04)	1 gm ft (= 04)	2 gm ft (= 04)	2 gm ft (= 04)					
66	Asymptotic glide slope capture made armed	1 gm ft (= 07)	1 gm ft (= 07)	2 gm ft (= 07)	2 gm ft (= 07)	1 gm ft			2 MS flag (= 02)	
67	Asymptotic glide slope capture	1 gm ft (= 06)	1 gm ft (= 06)	2 gm ft (= 06)	2 gm ft (= 06)				2 MS flag (= 03)	
68	Asymptotic ILS approach make		2 gm ft (= 30C only)							
70	Flight director speed command made armed		2 L 1 flag							
72	Go-around mode engaged			2 gm ft					2 MS flag	
73	81 mode/steer mode in use							2 gm ft		
74	Alpha speed hold Asymptotic mode in use							2 gm ft	1 MS flag	
75	Assigned hold mode in use							2 gm ft	2 MS flag	
76	Revert (fly) mode/capture mode in use							2 gm ft		
77	855 mode make armed							2 MS flag		
78	855 mode/capture mode armed							2 MS flag		
79	VOR mode make armed							2 MS flag		
80	VOR mode/capture mode armed							2 MS flag		
81	Altitude capture mode armed							2 MS flag		
82	Localizer/capture mode armed							2 MS flag		
83	Localizer capture mode armed							2 MS flag	1 MS flag & 2 MS flag	
84	ILS mode/capture mode armed							2 MS flag		
85	ILS capture mode armed							2 MS flag		
86	Autoland mode armed							2 MS flag	1 MS flag & 2 MS flag	

△ On the DC-10, these lights are part of the multi-lamp automatic flight mode indicator, not individual light units.



Automatic flight control system (where S)

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	701/720	727	737	747	DC-8	DC-9	DC-10	1-1811	
107 RCS track mode engaged							2 gns lbs		
108 VOR capture mode engaged forward							2 gns lbs	2 mb flaps	
109 VOR track mode engaged							2 gns lbs	2 mb flaps	
110 Roll CRS engaged							2 gns lbs		
111 Back course capture mode engaged							2 gns lbs		
112 Back course track mode engaged							2 gns lbs		
113 Localizer capture mode engaged forward							2 gns lbs	2 mb flaps	
114 Localizer track mode engaged							2 gns lbs	2 mb flaps	
115 Runway alignment mode engaged							2 gns lbs	2 mb flaps	
116 Roll out mode engaged							2 gns lbs	2 mb flaps	
117 Roll go-around mode engaged							2 gns lbs		
118 Roll holdoff mode engaged							2 gns lbs		
119 VOR course capture mode engaged							2 gns lbs	2 mb flaps	
120 Autopilot out of trim					1 mb fl		2 mb fl		
121 Aligned hold mode engaged			1 gns lb				2 gns lb 1 mb fl	1 mb fl & 2 mb flaps	
122 Back hold mode engaged							2 gns lb 1 mb fl	1 mb fl & 2 mb flaps	
123 Trackhold mode engaged							2 gns lbs	1 mb fl & 2 mb flaps	
124 Vertical speed mode engaged			1 gns lb				2 gns lbs	1 mb fl & 2 mb flaps	
125 Altitude capture mode engaged							2 gns lbs		
126 Altitude hold mode engaged			1 gns lb				2 gns lbs	1 mb fl & 2 mb flaps	

△ On the DC-10, these lights are part of the mode legend indicating flight mode transitions, not individual light units.

	Alerting functions	Type of alert								Applicable Federal aviation regulations (FAR)
		707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	
126	Pitch CMS engaged							2 ops hrs		
127	Glide slope capture mode engaged							2 ops hrs		
128	Glide slope track mode engaged							2 ops hrs		
129	Flare mode engaged							2 ops hrs	2 auto flaps	
130	Pitch go-around mode engaged							2 ops hrs		
131	Pitch rollout mode engaged							2 ops hrs		
132	Roll mode not available								10 auto hr	
133	Autoland selected and no autopilot engaged								2 auto flaps	
134	Automatic runway alignment mode failure								2 auto flaps	
135	Flight director glide slope capture mode activated									20 1 flaps
136	Autopilot & glide path capture activated						1 auto hr			
137	Glide path on						1 auto hr			

△ On the DC-10, these lights are part of the mode 2 display and are not illuminated when the autopilot is engaged.

Communications		Type of alert								Applicable Federal aviation regulations (FAR)	
Alerting function		707/720	721	737	747	DC-8	DC-9	DC-10	L-1011	SAC-111	
1	Service interphone action								1 min it		
2	Flight station call								1 min it		
3	Alternate SATCOM amplifier in use				2 min it						
4	Microphone/intercom combination selected		3 min it	15 sec it	10 min it	8 min it		10 min it & 3 min it			
5	Ground crew call	1 min it			1 min it & chime for continuous & 1 min it (loud)					7 min it	121.319 (d) The crewmember interphone system required by paragraph (b) of this section must be represented in accordance with Section 21.205 of this chapter and must be the following requirements: (i) For large transport category airplanes—(1) It must have an alerting system incorporating visual or visual signals for use by flight attendants to alert flight attendants and for use by flight attendants to alert flight attendants; (ii) The alerting system required by paragraph (b) (5) (ii) of this section must have a means for the recipient of a call to determine whether it is a normal call or an emergency call.
6	Attendant call	1 min it & chime	1 min it & chime	1 min it & chime			1 min it			1 min it & chime	
7	Flight interphone on				1 min it						
8	Cockpit call (forward incoming call)				1 min it & chime (+5)	chime	chime	6 dual legend whistle it, 1 min it & chime	1 min it & chime		
9	Cockpit call (forwarding all stations or pilot priority call)				1 min it & chime (+5)						
10	PA on		1 min it		1 min it	1 min it	1 min it	1 dual legend whistle it	2 min it		
11	VHF remote channel selected by transfer switch		4 sec it	6 sec it	6 sec it			4 sec it	6 sec it		
12	SELCAL selected	2 min it & chime	2 min it & chime	2 min it & chime	2 min it & chime	3 min it & chime	2 min it & chime	2 min it & chime	2 min it & chime		
13	HF band flight	2 min it									
14	Tape on tape communication monitoring	1 min it									
15	Tape communication playing	1 min it									
16	Tape communication stopped	1 min it									
17	VDR test warning	2 min it					2 min it				

	Alerting function	Type of alert						Applicable Federal aviation regulations (FAR)			
		707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
1	Galley power off				4 aural			3 aural	3 aural		
2	APU generator oil overheat								1 aural		
3	APU generator low oil pressure								1 aural		
4	External power available	2 clear	1 clear	1 lib	2 aural	1 lib	2 lib	1 gen	1 gen	1 aural	
5	External power on	2 lib			2 gen			1 lib	1 aural		
6	Generator field relay tripped open	4 aural	3 aural		4 aural				4 aural		
7	Generator differential fault		3 aural						4 aural		
8	Generator bearing fault				4 aural				4 aural		
9	Flight engine AC bus failure								3 aural		
10	CSD or BSC oil temp high		3 yel	2 aural & 4 yel	4 yel		2 yel	3 aural & 4 yel	3 yel	2 aural ( $\approx 115^{\circ}\text{F}$ , 57.5 $\pm 7.6^{\circ}\text{C}$ )	
11	CSD or BSC low oil pressure	4 aural	3 aural	2 aural	4 aural	4 aural	2 aural	3 aural	3 aural	2 aural ( $\approx 10.4\text{ psi}$ , 57.5 $\pm 7.6^{\circ}\text{C}$ )	
12	Generator breaker or relay tripped open	4 aural	3 aural	2 lib	4 aural			3 aural	4 aural		
13	AC bus tie open	4 aural	3 aural		4 aural	4 aural ( $\approx 36.1$ )		3 aural & 3 lib	3 aural		
14	AC standby bus fail/off			1 aural					3 aural & 2 lib ( $\approx 15$ )		
15	DC standby bus fail								3 aural ( $\approx 94$ )		
16	AC essential bus fail or off	1 aural	1 aural		2 aural				1 aural		
17	DC essential bus fail								1 aural		
	DC tie breakers open & DC busbars isolated from DC tie bus				3 gen				1 aural		
	Essential AC bus on alternate power source	1 aural							1 aural		
	AC and/or DC standby busbars switched to battery bus								1 aural		

Alerting functions	Type of alert							Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-9	DC-10	L-1011	BAC-111
Standby power switch or battery switch off							1 red lt	
Ground service buses energized							1 red lt	
Standby power on				1 green lt				
Essential master radio power off							2 amber lts	
Emergency power in use alert		1 amber lt			1 red lt	2 red lts		
APU power available						2 blue lts	1 green lt	
AC bus on APU						2 blue lts		
AC bus on ext. power						2 blue lts		
AC circuit breaker						1 amber lt		
Ground service bus on APU power						1 blue lt		
Ground service bus on external power						1 blue lt		
Generator feeder fault						2 amber lts		
Generator off						2 amber lts		
AC bus off		2 amber lts			4 amber lts (+ 13)	2 amber lts	3 amber lts	2 red lts
AC emergency bus off					2 red lts	1 red lt	2 red lts	
DC bus off						1 amber lt	3 amber lts	1 red lt
DC transfer bus off						1 amber lt		
DC emergency bus off						1 red lt	2 red lts	

25.1185 (d) There must be means to warn appropriate flight crewmembers of the malfunctioning of any part of the electrical system if causing the continuous discharge of any battery necessary for engine ignition.

25.1185 (d) (5) Nickel cadmium battery installations capable of being used to start an engine or auxiliary power unit must have—(5) A battery temperature sensing and over-temperature warning system with a means for disconnecting the battery from its charging source in the event of an over-temperature condition; and (6) A battery failure warning and warning system with a means for disconnecting the battery from its charging source in the event of battery failure.



Alerting function	Types of alert							Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-8	BAC-111	
Spill system handle open				1 ym it				
APU generator bearing failure				2 amb it				
APU generator field off		1 amb it		2 amb it				
APU generator relay open		1 amb it	1 amb it	2 amb it				
CSD oil pump low				4 yd sounds				
DC motor winding selected				5 light it				
AC motor winding selected				5 light it				
Generator fault				4 amb it	4 amb it	3 amb it	3 amb it	
Generator control unit fault				4 amb it				
CSD fault				4 amb it			2 amb it (+ 55, 57 53 & 56)	
Load control fault				4 amb it				
Generator fault	4 red it			4 amb it				
AC bus synchronization		2.8 clear it						
APU generator fault				2 amb it		1 amb it	1 ( 1) it	
APU bus power unit fault				2 amb it				
APU generator fault				2 amb it	1 amb it			
AC overvoltage		3 amb it				1 undelyt beam (+ 55, 57 53 & 56)		
AC undervoltage		3 amb it				1 undelyt beam (+ 55, 57 53 & 56)		
AC system over voltage		3 amb it				1 undelyt beam (+ 55, 56 53 & 56)	2 amb it (+ 55, 57 53 & 56)	

Electrical systems (sheet 4)

Alerting func.: no	Type of alert							Applicable federal aviation regulations (FAR)
	701/720	727	737	747	DC-8	DC-9	DC-10	
58 AC system under control		3 amb its					1 undupl hand (1-55, 56, 57)	
59 Phase unbalance		1 amb its						
60 AC transfer bus off			2 amb its					
61 Electrical system fault			1 amb its				1 amb its	
62 APU generator off						1 amb its	1 amb its	
63 APU power in use							3 Ecu its	
64 AC overheat					1 amb its		3 yel bands	
65 DC circuit closed							3 M. its	
67 DC overheat							4 yel bands	
68 Dual load disconnect system operating mode selected							1 blue its	
69 Dual load power on							1 yel its	
70 Battery bus-CT							1 amb its	
71 Galley external power available							1 yel its	
72 Galley external power in-use							1 blue its	
73 Cabin bar power off							1 amb its	
74 APU ac available							1 yel band	
75 Emergency bus off							1 amb its	
76 Turbine overtemp								2 amb its (1-55, 56, 57)
DC system voltage limitations							1 amb, 1 yel, 3 yel & 2 yel bands	

Alerting function	Type of chart									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
AC or DC essential or standby functions								18 and 24		
Equipment required					4 main line					

Alerting function	Type of alert									Applicable Federal aviation regulations (FAR)
	703/726	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
Excursion command activated	1 R and 1 G bars	1 R and 1 G bars		1 R and 1 G bars & chime		1 R and 1 G bars	1 R and 1 G bars	1 R and 1 G bar		25.812 (4) (2) There must be a light comprising light which illuminates when power is on in the cockpit and emergency lighting control device is either armed or turned on.  25.815 (4) For economy, auxiliary, and emergency controls—(1) Each emergency control (including each fuel jettisoning and fuel shutoff control) must be colored red.
Oxygen press low							2 white hands			
Passenger oxygen system on	1 amber ft	1 amber ft	1 amber ft	2 amber ft		1 blue ft		1 green ft		
Oxygen flow-pressure regulator	3 white flags	3 white flags	3 white flags	3 white flags		1 white flag		1 white flashing flag		
Emergency lights not armed		1 amber ft	1 amber ft		1 amber ft	1 amber ft	1 amber ft	1 amber ft		
Emergency lights test ok							1 green ft			
Excursion command system energized								1 amber ft		

25.912 (4) (2) There must be a light concerning light which illuminates when power is on in the airplane and emergency lighting control device is either armed or turned on.

25.955 (4) For emergency, landing, and emergency controls—(1) Each emergency control (including each fuel jettisoning and fuel shutoff control) must be colored red.

Alerting function	Type of alert									Applicable Federal aviation regulations (FAR)
	703/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
Master fire warning	Full	2 red ltr 0 full	2 red ltr 0 full	2 red ltr 0 full				2 red ltr 0 full		25.1200(d) There must be a means for each fire extinguishing agent container to indicate that the container has discharged or that the charging pressure is below the established minimum necessary for proper functioning.
Fire extinguisher handle discharge	4 amber ltr	2 red ltr	3 amber ltr	11 ltr & 11 amber ltr	4 amber ltr	2 amber ltr	6 amber ltr	8 amber ltr		
Engine & APU fire extinguishing system circuit ok								8 amber ltr		
Engine & APU fire detection system activated (full)		6 amber ltr				6 amber ltr	8 amber ltr	10 amber ltr (+ 17, 20)		
Mixed wall fire detection system activated (full)										
Engine overheat			2 amber ltr		4 yellow ltr	2 yellow ltr	3 amber ltr & 3 yellow ltr	3 red ltr & 3 red ltr	2 red ltr	25.1200(d) There must be a means to allow the crew to check, in flight, the functioning of each fire or overheat detector electric circuit.
Engine overheat detection system circuit ok								2 red ltr		
Galley smoke								10 amber ltr (+ 18) 0 ltr		
Galley overheat							1 amber ltr (+ 9) 0 ltr			
Hotbleed/Pyro overheat				4 red & red ltr on each engine indicators				30 amber ltr		
Engine fire	6 red ltr	3 red ltr	2 red ltr	4 red ltr	4 red ltr	2 red ltr 0 full	4 red ltr 0 full	3 red ltr	2 red ltr 0 full	25.1300 The following are required master/warning instruments: (a) For all airplanes. (b) For warning indicators.
APU fire		1 red ltr	1 red ltr	2 red ltr		1 red ltr	2 red ltr	1 red ltr	1 red & 0 full	
Mixed wall fire		1 red ltr	1 red ltr	1 red ltr				10 red ltr		25.1600(c) If action by the flight crew is required to prevent or minimize a fluid fire i.e., equipment shutdown or activation of a fire extinguishing agent, action must be provided to alert the crew.
Cargo compartment smoke	1 red ltr (except only)		2 red ltr	3 red ltr						
Fire handle up/down ok			3 red ltr	6 red ltr						
Engine fire detector failure				2 red ltr		1 red ltr (+ 20)		6 amber ltr (+ 5, 20)		25.1200(d) Each fire detector system must be constructed and installed as described in this FAR. There must be a means to allow the crew to check, in flight, the functioning of each fire or overheat detector electric circuit. In the case of a fluid fire, the system must function as a satisfactory detector to allow the flight crew to take action.

Fire protection (Sheet 2)

Alerting function	Type of alert							Applicable Federal aviation regulations (FAR)
	WU/720	721	731	747	DC-9	DC-10	L-1011	BAC-111
20 Sharp tone production system operation				2 per hr				
20 APU fire detector loop fault				2 audible				
20 Smoke detector system on	4 per hr (except early)							
21 Smoke	4 audible (except early)							
22 Engine over heat		3 per hr						
23 Engine overheat or APU fire detector loop			1 per hr					
24 APU fire detection system failure			1 per hr		1 audible (1-107)		2 audible (1-5,107)	
Fire bell installed								1 audible
Handheld fire overheat detection system failure or test							6 audible	

Alerting function	Type of alert							Applicable Federal aviation regulations (FAR)
	700/720	727	737	747	BC-8	BC-9	BC-10	
1								1 red ft
2								4 red ft
3								4 red ft
4								4 red ft
5								2 red ft
6								5 red ft
7								5 red ft
8						1 red ft (1-10)		1 red ft
9						1 red ft (1-10)		1 red ft
10								1 red ft
11								1 red ft
12								1 red ft
13								2 red ft
14								2 red ft
15		1 red ft (1-10)						2 red ft
16		1 red ft (1-10)	1 red ft	1 red ft				1 red ft
17		2 red ft	2 red ft	2 red ft	2 red ft	2 red ft	2 red ft	2 red ft
18								2 red ft
19								2 red ft

25.2000. The warning may be furnished either through the adjacent engine compartment or by a device that will give clearly distinguishable indication under repeated conditions of flight. However, a red light warning device that requires the attention of the crew within the cockpit is not acceptable by itself.

Alerting functions	Type of alert								Applicable Federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	
Direct Electric spoiler off								2 wdt ltr	BAC-111
Direct Hydraulic spoiler fail								2 wdt ltr	
Auto thrust off								2 wdt ltr	
Auto thrust fail								2 wdt ltr	
Mach trim off	1 wdt ltr (-25)							2 wdt ltr	
Mach trim fail	1 wdt ltr (-24)		1 wdt ltr			1 wdt ltr	2 ltr lt (-70, 71 & 72)	2 wdt ltr	1 wdt ltr (-105)
Slats locked								2 wdt ltr	
Slat monitor system (S)								1 wdt ltr	
Leading edge flaps & slats extension failure		14 gnd lt 14 wdt ltr	12 gnd lt 10 wdt ltr	10 wdt lt 10 gnd ltr	1 wdt ltr			10 gnd ltr	
Pitch trim compressor >90% or fail									
Speed brake handle not down and flaps extended		More (-) used for low cabin pressure							
Mechanical roller limiter incorrect position								2 wdt ltr 10 wdt ltr	
Automatic mechanical roller limiter disarmed								1 wdt ltr	
Rollbar limit unarmored						1 wdt ltr		1 wdt ltr	
Rollbar limit limited								1 wdt ltr	
Out-of-lim both wings clipped								2 yrd flaps	
Leading edge slats or flaps in transit		1 wdt ltr	1 wdt ltr	2 wdt ltr (-40)				1 wdt ltr	
Leading edge slats fully extended		1 gnd lt (-40)	1 gnd ltr					1 gnd ltr	



Alerting functions	Type of alert									Applicable Federal Aviation Regulations (FAR)
	767/728	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
40 Landing edge flap extended	2 ga. lts	1 ga. lt (+ 20)	1 ga. lt	2 ga. lts (+ 20)						
41 Elevator hydraulic pressure						1 lts lt				
42 Auto spoiler system failure						1 each lt	1 each lt	1 lt each lt		
43 Spoiler handle handle not released						1 each lt	1 lt each lt			
44 Elevator nose off						1 each lt				
45 Aft nose nose off						1 each lt		4 each lt		
46 Stabilizer not at zero		1 each lt	1 each lt			1 each lt				
47 Auto trim trim system failure				2 each lts						
48 Yaw damper failure		2 gal. lts	1 each lt	2 each lts			2 each lts			
49 Reducer valve compressor circuit closed				1 each lt						
50 Reducer valve discrepancy				1 each lt						
51 Flight controls hydraulic pressure cutoff				8 each lts					2 each lts	
52 Stabilizer trim operating	1 each lt	1 each lt	1 each lt							
53										
54										
55 Reducer and spoiler hydraulic pump low pressure	1 each lt									
56 Spoiler trim failure	Checker	Checker	Checker	Checker	More fan (+ 80 minutes)	More fan	More fan			
57 Aft trim hydraulics efficiency control					1 each lt					
58 Elevator hydraulics low pressure		2 each lts (+ 50, 80)	2 each lts (+ 50, 80)							
59 Reducer hydraulics low pressure	1 each lt & 2 ga. lts & 1 gal. lts	2 each lts	2 each lts (+ 50, 80)					1 each lt		
60 Aft trim hydraulics low pressure		2 each lts	2 each lts (+ 50, 80)							

Flight controls (Sheet 4)

Alerting function	Type of alert							Applicable federal aviation regulations (FAR)	
	703/720	727	737	747	DC-8	DC-9	DC-10		L-1011
61 Reducer fuel limiter failure		1 awh lt							
62 Stick trim control limiter failure				2 awh fls					
63 Flight control system malfunction			1 awh lt					1 lt awh lt	
64 Reducer or elevator feel differential pressure indication		1 awh lt	1 awh lt						
65 Speed limiter—do not use		1 awh lt	1 awh lt						
66 Speed limiter exceed			1 gwh lt						
67 Yaw damper test in progress							1 ltr dual legend lt		
68 Yaw damper test failure							2 awh fls		
69 Auto slat extension system fault							1 awh lt		
70 Flap limit system failure (1 channel)							1 ltr lt (+20)		
71 Flap limit system failure (all channels)							1 awh lt (+20)		
72 Flap limit extension							1 ltr lt (+20)		
73 Indirect flap position display							2 awh flap		
74 Flap limit speed indication failure							1 gwh flap		
75 Reducer standby power off					1 ltr lt		1 awh lt		
76 Elevator feel system loop (1 channel)							1 ltr lt		
77 Elevator feel system loop (all channels)							1 awh lt		
78 Elevator emergency power to use									1 awh lt
79 Flap primary slack failure									1 awh lt
80 Brake wheel configuration	Intermittent fail	Intermittent fail	Intermittent fail	Intermittent fail	Intermittent fail	Intermittent fail	Intermittent fail	Intermittent fail	None
81 Reducer travel—not in agreement						1 awh lt			
82 Flap limit relief system failure								1 lt awh lt legend lt	

Flight Controls (cont'd)

Alerting function	Type of alert								Applicable Federal aviation regulations (FAR)
	703/726	723	733	747	DC-8	DC-9	DC-10	1-1811	
83 Spoiler extended					1 sec. it				
85 Spoiler control manual					1 sec. it (+3)	1 sec. it (+3)			
86 Wing slats					1 sec. it				
87 Spoiler hydraulic pressure in excess for flight condition								10 sec. it	
88 Spoiler hydraulic pressure in excess for flight condition								10 sec. it	
89 Spoiler hydraulic pressure in excess for flight condition								10 sec. it	
90 Spoiler hydraulic pressure in excess for flight condition								4 sec. it	
91 Spoiler hydraulic pressure in excess for flight condition								4 sec. it	
92 Spoiler hydraulic pressure in excess for flight condition								1 sec. it	
93 Spoiler hydraulic pressure in excess for flight condition								1 sec. it	
94 Spoiler hydraulic pressure in excess for flight condition								1 sec. it	
95 Spoiler hydraulic pressure in excess for flight condition									1 sec. it
96 Spoiler hydraulic pressure in excess for flight condition									
97 Spoiler hydraulic pressure in excess for flight condition									1 sec. it
98 Spoiler hydraulic pressure in excess for flight condition									2 sec. it
99 Spoiler hydraulic pressure in excess for flight condition									2 sec. it
100 Spoiler hydraulic pressure in excess for flight condition									1 sec. it
101 Spoiler hydraulic pressure in excess for flight condition									2 sec. it
102 Spoiler hydraulic pressure in excess for flight condition									1 sec. it
103 Spoiler hydraulic pressure in excess for flight condition									2 sec. it
104 Spoiler hydraulic pressure in excess for flight condition									1 sec. it
105 Spoiler hydraulic pressure in excess for flight condition									1 sec. it (+3)
106 Spoiler hydraulic pressure in excess for flight condition									2 sec. it
107 Spoiler hydraulic pressure in excess for flight condition									
108 Spoiler hydraulic pressure in excess for flight condition									
109 Spoiler hydraulic pressure in excess for flight condition									
110 Spoiler hydraulic pressure in excess for flight condition									
111 Spoiler hydraulic pressure in excess for flight condition									
112 Spoiler hydraulic pressure in excess for flight condition									
113 Spoiler hydraulic pressure in excess for flight condition									

Alerting function	Type of alert									Applicable Federal aviation regulations (FAR)
	701/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
1 $V_{ref}$ indication fail								2 red flag		121.309(d) Except as provided in paragraph (b) of this section, after June 1, 1976, no person may operate a large turbine-powered airplane unless it is equipped with a ground proximity warning system. The required ground proximity warning system shall be a terrain clearance system.
2 Mach indication fail		2 red flag		2 red flag				2 red flag		
3 Acceleration indication fail								2 red flag		
4 Radio altimeter failure		2 red flag & 2 (1) red flag (-5)				2 red flag				
5 Radio altitude info fail	2 red flag	2 red flag & 2 (1) red flag (-4)	2 red flag	2 red flag	2 red flag	2 red flag	2 red flag	2 red flag		
6 Turn and slip indicator/info fail					2 red flag					
7 Instrument source selection										
8 Attitude display disagree				True			Master (green)	14 amber flag		
9 Instrument indication comparison	6 red flag & chime	12 red flag & chime	12 red flag & chime	2 red flag & chime		12 amber flag		8 amber flag		
10 Instrument comparison monitor failure	1 red flag	2 red flag	2 red flag			2 amber flag		8 amber flag		
11 Static source error correction failure	2 amber flag	2 amber flag	2 amber flag			2 amber flag		2 red flag		
12 Barometric altitude info failure			2 green flag		2 red flag		2 amber flag	2 red flag		
13 Vertical speed info fail							2 amber flag	2 red flag		
14 Static air temp fail				1 red flag			1 amber flag (-15)	1 red flag		
15 True airspeed fail				1 red flag	1 red flag		1 amber flag (-14)	1 red flag		
16 Standby attitude fail/off	1 red flag	1 red flag	1 red flag	1 red flag	1 red flag	1 red flag	1 red flag	1 red flag		
17 Ground proximity warning	2 red flag & chime	2 red flag & chime	2 red flag & chime	2 red flag & chime	1 red flag & chime	2 red flag & chime	2 red flag & chime	2 red flag & chime	Master & message	
18 Before glidepath warning	2 red flag & chime	2 red flag & chime	2 red flag & chime	2 red flag & chime	2 red flag & chime	2 red flag & chime	2 red flag & chime	2 red flag & chime	(7)	

121.309(a) Except as provided in paragraph (b) of this section, after June 1, 1978, no person may operate a large turbine-powered airplane unless it is equipped with a ground proximity warning system.

37.201(a) (3) Alert and visual warnings. The required alert and visual warnings must operate simultaneously (4) Description required. If the equipment incorporates a detection control other than a circuit breaker, the control must be a switch with a protection cover. The

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
19 Ground proximity system fail	1 amb lts	1 amb lts	1 amb lts	1 amb lts	1 amb lts	1 amb lts	1 amb lts	1 amb lts	
20 500 foot terrain warning		Tone		Tone		2 second beep tone		Beep tone	
21 Decision height MDA	2 blu lts & tone	2 amb lts & tone	2 amb lts & tone	2 amb lts & tone	2 amb lts	2 amb lts & tone	2 amb lts	2 amb lts & tone	
22 Below sea level				2 red flags					
23 Total air temp indications bad	1 yel flag	1 yel flag	1 red flag	1 red flag & 1 yel flag			1 orn flw.		
24 Over outer marker	1 blu lts	2 blu lts	2 fl blu lts	2 blu lts	2 blu lts	1 blu lts	2 blu lts	2 blu lts	2 fl blu lts
25 Over middle marker	1 amb lts	2 amb lts	2 fl amb lts	2 amb lts	2 amb lts	1 amb lts	2 amb lts	2 amb lts	2 fl amb lts
26 Airways marker beacon	1 clear lts	2 clear lts	2 fl clear lts	2 clear lts	2 clear lts	1 clear lts	2 clear lts	2 wht lts	2 fl wht lts
27 CAOC switched							1 amb lts		
28 Excessive air speed or mach	Bell	Clacker	Clacker	Clacker	2 red lts & clacker	Clacker & 4 yel red bands	Clacker	Clacker	Intermittent bell
29 RMI failed							2 orn flags		

cover must be safety wired so that the wire must be broken in order to gain access to the switch

(Note: Specific requirements for these alerts provided in RTCA Document No. DO-161A. These requirements are summarized in Appendix E, Table E-5.)

25 1303(c) (1) A speed warning device is required for turbine engine powered airplanes and for airplanes with  $V_{mo}$   $M_{mo}$  greater than 0.8 Vg/Mg. The speed warning device must give effective aural warning (differing distinctively from aural warnings used for other purposes) to the pilot, whenever the speed exceeds  $V_{mo}$  plus 6 knots or  $M_{mo} + 0.01$ . The upper limit of the production tolerance for the warning device may not exceed the prescribed warning speed.

91.49 Aural speed warning device. No person may operate a transport category airplane in air commerce unless that airplane is equipped with an aural speed warning device that complies with Section 25.1303(c) (1).

Alerting function	Type of alert									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
1 Fuel Limiting system overridden								3 wht lts		25 1305 The following are required powerplant instruments: (a) For all airplanes, 1) A fuel pressure warning means for each engine, or a master warning means for all engines with provisions for isolating the individual warning means from the master warning means
2 Fuel jettison valves operating in automatic dump control mode							2 amb lts	4 amb lts		
3 Jettison valves in transit	5 blu lts	6 blu lts		6 blu lts				2 blu lts		
4 Master jettison control switch status								1 amb lt		
5 APU emergency shutoff valve in transit								2 amb lts		
6 Engine fuel shutoff valve in transit	4 blu lts	3 blu lts	2 brt blu lts ( * 23 )	4 wht lts				3 blu lts		
7 Cross-ship fuel isolation valves in transit								1 blu lt		
8 Master switch at refuel panel armed								1 amb lt		
9 Fuel quantity readout selection								2 wht lts		
10 Fuel quantity low					2 amb lts			2 amb lts		
11 Fuel boost pump low pressure	10 amb lts	8 amb lts	6 amb lts	10 amb lts	4 amb lts & 4 green/red bands	6 amb lts	12 amb lts	8 amb lts	2 red lts	
12 Engine fuel pump low pressure								3 amb lts	2 amb lts	
13 Fuel used indication bad				4 ( ) flags						
14 Fuel flow indicator failure				4 yel flags						
15 Fuel filter icing	4 amb lts	3 amb lts	2 amb lts	4 amb lts						
16 Fuel temp readout selected				5 blu/whit lts						
17 Scavange pump pressure lost				1 amb lt						
18 Reserve tank fuel valve in-transit	2 blu lts			2 blu lts						
19 Crossfeed valve in transit	4 blu lts	3 blu lts	1 brt blu lt ( * 26 )	4 blu lts				3 blu lts		
20 Fuel jettison pump low pressure				4 amb lts						

Fuel (sheet 2)

Alerting function	Type of alert								Applicable federal aviation regulations (FAH)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
21 Fuel jettison dump chute not retracted and latched	2 amb lts								
22 Fuel crossfeed valve position disagrees with switch position							3 amb lts		
23 Engine fuel shutoff valve closed			2 dim blu lts ( * 6 )		4 blu lts				
24 Fuel heat valve open			2 dim blu lts ( * 25 )			2 blu lts			
25 Fuel heat valve in-transit			2 brt blu lts ( * 24 )						
									23.1305(c) For turbine engine powered airplanes. In addition to the powerplant instruments required by paragraph (e) of this section, the following power plant instruments are required: (8) An indicator to indicate the proper functioning of any heater used to prevent ice clogging of fuel system components.
26 Crossfeed valve open			1 dim blu lt ( * 19 )						
27 Fuel system malfunction			1 amb lt				1 fl amb lt	1 amb lt	
28 Fuel usage or transfer off schedule							2 amb lts		
29 Fuel fill valve open							3 blu lts		
30 Tank overfilled							1 amb lt		
31 Fuel used indication reset								1 wht lt	
32 Emergency shutoff valve in-transit								4 amb lts	
33 Fuel jettison valves in-transit								4 blu lts	
34 Alternate tank fuel shutoff valve closed					4 blu lts				

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Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	
1 ATM oil temp high								2 amb lts	
2 ATM oil pressure low								2 amb lts	
3 ATM pump high temp								3 amb lts	
4 ATM pump low press								3 amb lts	
5 Ram air turbine unlocked								1 amb lt	
6 Ram air turbine pressure being supplied								1 grn lt	
7 Reservoir fluid quantity low	2 amb lts			4 grn bands & 4 amb lts		2 red bands	3 yel bands	4 amb lts	
8 Reservoir fluid temp high							3 yel bands	4 amb lts	2 red lts
9 Pump suction valve closed								4 wht lts	
10 Pump depressurizing valve closed								4 wht lts	
11 AC pump on								2 wht lts	
12 Engine driven dump case drain fluid high temperature								3 amb lts	
13 Engine driven pump low output pressure	4 amb lts	2 amb lts	2 amb lts	4 amb lts				3 amb lts	
14 Hydraulic temp hi	1 red lt	3 amb lts			1 amb lt & 1 red band	2 amb lts	6 amb lts & 3 yel bands		1 red lt
15 Hydraulic pressure low		2 grn/yel/red bands		4 amb lts		2 amb lts	6 amb lts & 3 orn bands		2 amb lts (* 22, 30)
16 Hydraulic pump case drain fluid temp high			2 amb lts	4 amb lts					
17 Air driven pump low pressure				4 amb lts					
18 Standby system hydraulic fluid quantity low			1 amb lt		1 amb lt				
19 Air driven pump operating				4 blu lts					
20 Break interconnect valve open		1 grn lt							
21 Electric driven pump low output pressure		3 amb lts	2 amb lts						



Alerting function	Type of alert									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
22 Hydraulic system malfunction			1 amb lt				1 amb lt	1 fl amb lt	2 amb lts ( * 15, 30 )	
23 Hydraulic pressure abnormal			1 grn, 2 yel & 1 red band			2 grn bands				
24 Hydraulic filter pressure high							1 blu lt			
25 Auxiliary hydraulic pump(s) on					1 blu lt		3 blu lts			
26 Hydraulic system ground test controls							3 amb lts			
27 Ram air turbine deployed								1 fl amb lt		
28 Power transfer unit on								2 wht lts		
29 Auxiliary hydraulic pump overheat									1 amb lt	
30 Hydraulic reservoir air pressure low									2 amb lts ( * 15, 22 )	
31 Standby hydraulic pump—low pressure			1 amb lt							
32 Utility hydraulic pumps—low pressure	2 amb lts & 1 grn 2 yel & 2 red bands									

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
1 Wing anti-ice duct failure		1 amb lt (° 34, 35)						2 amb lts	
2 Wing anti-ice on						1 blu lt	1 blu lt	4 wht lts	
3 Wing anti-ice temp hi	1 amb lt					2 amb lts		2 amb lts	
4 Engine anti-ice heat available in cowl leading edge								3 grn lts	
5 Engine anti-ice on					4 amb lts	2 blu lts	1 blu lt	3 wht lts	
6 Engine anti-ice over pressure								3 amb lts	
7 Engine anti-ice valve and switch disagreement		3 grn lts				2 amb lts	3 amb lts (° 38)		
8 Wing anti-ice auto tripped to off		1 amb lt							
9 Pitot heat off							1 amb lt	4 amb lts	
10 Temperature probe heat off								2 amb lts	
11 Angle of attack sensor heat off								2 amb lts	4 amb lts
12 Pitot heat on	3 blu lts	2 blu lts	7 grn lts	6 grn lts		1 blu lt			
13 Tail de-ice on					1 amb lt	1 blu lt			
14 Airfoil anti-ice press low						1 amb lt			
15 Nacelle anti-ice press high				4 amb lts					
16 Wing anti-ice valve in transit			2 brt blu lts (° 37)	2 blu lts					
17 Waste water pump failure								2 amb lts	
18 Insufficient heat in drain masts								4 amb lts	
19 Temperature probe and scat heat on	2 blu lts								
20 Window underheat						1 amb lt			2 amb lts
21 Window heat fault							2 amb lts	6 amb lts	

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
22 Defog fan on/off switch status								1 wht lt	
23 Window overheat	2 amb lts	4 amb lts	4 amb lts	3 amb lts		1 amb lt			2 amb lts
24 Window heat on/off		4 grn lts	4 grn lts	6 grn lts				6 wht lts	
25 Windshield washer pump on								1 amb lt	
26 Nacelle valve position synched with switch	4 grn lts ( * 27 )								
27 Nacelle anti-ice valve open	4 grn lts ( * 26 )			4 grn lts					
28 Stator anti-ice valve open				4 grn lts					
29 Window heat lights operating mode									
30 Window heat test				1 blu/wht lt					
31 Window overheat test				1 blu/wht lt					
32 Altitude warning transducer heat on	2 blu lts			1 blu/wht lt					
33 Q-inlet heater fail/off	1 amb lt								
34 Engine 2 anti-ice duct overheat		1 amb lt ( * 1, 35 )							
35 Wing anti-ice duct overheat		1 amb lt ( * 1, 34 )							
36 Wing anti-ice valve and switch disagreement		2 grn lts					2 amb lts		
37 Wing anti-ice valve open			2 dim blu lts ( * 16 )					2 wht lts	
38 Engine anti-ice valves in transit			6 brt blu lts ( * 39 )				3 amb lts ( * 7 )		
39 Engine anti-ice valves open			6 dim blu lts ( * 38 )						
40 Anti-ice system malfunction			1 amb lt						
41 APU anti-ice on							1 blu lt		

Alerting function	Type of alert									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
42 Ice protection temp low						2 amb lts				
43 Rain repellent reserve in use						1 blu lt				
44 Nozzle overheat								3 amb lts		
45 Ice forming on icing probe								1 fl amb lt		
46 VHF antenna anti ice failure								1 amb lt		
47 Ice protection press high						1 amb lt				

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
2 Gear door(s) open	1 red lt	1 red lt		1 red lt & 5 amb lts		1 amb lt		1 red & 3 amb lts	
3 Gear or doors in transit								1 red lt (• 4)	
4 Gear unlocked or gear & doors not in agreement with gear lever		3 red lts		1 red lt	1 red lt & horn	3 red lts (• 29, 31)	3 red lts (• 7, 29)	1 red lt (• 3)	1 red lt
5 Truck not level (in gear down position)	1 amb lt							1 amb lt	
6 Gear unsafe	1 red lt								
7 Gear down and locked	3 grn lts	3 grn lts	3 grn lts	6 grn lts	3 grn lts	3 grn lts	3 grn lts (• 4, 29)	3 grn lts	3 grn lts
8 Brake high temp				4 red bands & 4 amb bands		4 amb lts		1 amb lt & 1 fl amb lt	
9 Brake overheat				2 amb lts		4 red lts		1 red lt	
10 Anti-skid hydraulic valve not fully open				1 amb lt					
11 Anti-skid failure			2 amb lts (• 12)	21 amb lts	1 amb lt		4 amb lts	1 fl amb lt	
12 Anti-skid off			2 amb lts (• 11)			4 amb lts		2 amb lts	
13 Anti-skid system test ok								8 amb lts (• 14)	
14 Anti-skid operated	4 wht flags	5 amb lts						8 amb lts (• 13)	
15 Tail skid not in agreement with landing gear lever position		1 amb lt						1 amb lt	
16 Body gear not centered				1 amb lt					
17 Gear and gear door position lights operating mode				6 blu/whit lts					
18 Brakes—low pressure		1 grn 1 yel & 2 red bands		2 amb lts	1 red band	2 grn/ red bands		2 amb lts & 1 fl amb lt & 2 yel bands	
19 Secondary system supplying brake pressure				1 grn lt					
20 Brake pressure indicator off								1 red flag	
21 Reserve brake valve open				1 grn lt					

25.729(c) If a retractable landing gear is used, there must be a landing gear position indicator or other means to inform the pilot that the gear is secured in the extended (or retracted) position.

Alerting function	Type of alert							Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10 ~ L-1011	8AC-111
22 Brake pressure abnormal			1 grn, 1 yel & 2 red bands					
23 Parking brakes on	1 red lt	1 red lt	1 red lt	1 red lt		1 amb lt	2 amb lts	1 red lt
26 Body gear steering hyd. Pressure available				1 amb lt				
27 Body gear steering cylinders unlocked				2 amb lts				
28 Gear compartment not sealed			1 amb lt					
29 Gear not down and locked & thrust lever at idle			3 red lts & horn (*30, 31, 38)			3 red lts & horn (*4, 31)	3 red lts & horn (*4, 7)	Horn (*34, 38)
30 Gear unlocked			3 red lts & horn (*29, 31, 38)					
31 Gear down and locked and lever not in down detent			3 red lts & horn (*29, 30, 38)			3 red lts (*4, 29)		
32 Equipment tire burst			1 amb lt					
34 Gear not down and locked with flaps extended beyond the approach position								Horn (*29, 38)
35 Gear not down & locked & throttle retarded to idle with flaps 1, 5, 10 or 20				Steady horn (*36, 38)				
36 Gear not down and locked with flaps 25 or 30				Steady horn (*35, 38)				
37 Gear not down and locked with flaps extended beyond 150						Horn		

25.729(e) (2) Landplanes must have an aural warning device that will function continuously when one or more throttles are closed, if the landing gear is not fully extended and locked. (3) If there is a manual shutoff for the warning device prescribed in subparagraph (2) of this paragraph, it must be installed to that reopening the throttles will reset the warning mechanism.

25.729(e) (4) Landplanes must have an aural warning device that will function continuously, when the wing flaps are extended beyond the maximum approach position determined under Section 25.67(e), if the gear is not fully extended and locked. There may not be a manual shutoff for this warning device.

121.283(e) Each large airplane must have a landing gear aural warning device that functions continuously under the following conditions: (1) For airplanes with an established approach wing flap position, whenever the wing flaps are extended beyond the maximum certificated approach climb configuration position in the Airplane Flight Manual and the landing gear is not fully extended and locked. (2) For airplanes without an established approach climb wing flap position, whenever the wing flaps are extended beyond the position at which landing gear extension is normally performed and the landing gear is not fully extended and locked. (b) The warning

Alerting function	Type of alert									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
										system required by paragraph (a) of this section—(1) May not have a manual shutoff; (2) Must be in addition to the throttle actuated device installed under the type certification airworthiness requirements.
Unsafe landing configuration	Horn	Horn	Horn ( ° 29, 30, 31 )	Horn ° 35, 36 )	Horn	Horn	Horn		Horn ( ° 29, 34 )	
Anti-skid on								1 grn lt		
Truck not tilted (in gear up position)				4 amb lts						

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
1 Altitude info unreliable or failure				2 red flags		2 red flags (• 5)	2 orn flags	2 red flags	
2 Approach gate info failure								2 red flags	
3 Slow-fast info failure		2 red flags		2 red flags		2 red/bk striped shutters	2 orn flags	2 red flags	
4 Rollout command info failure								2 red flags	
5 Flight director info failure	2 red flags	2 red flags	2 red flags	2 red flags	2 red flags	2 red flags	2 orn flags	2 red flags	2 red flags
6 Gyro failure	2 red flags	2 red flags	2 red flags		2 red flags	2 red flags (• 1)			2 red flags
9 Magnetic heading info fail				2 red flags			4 orn flags (• 46)		
10 Magnetic compass info unreliable								2 red flags	
11 Nav info failure	2 fl red lts			2 red flags	2 yel flags			2 red flags	2 ( ) flag
12 Compass system failure	2 red flags	2 red flags	4 red flags		4 red flags	2 red flags			
13 Compass caged	2 red flags								
15 Auxiliary vertical gyro inop			1 wht flag				1 amb lt	1 fl amb lt	
16 Drift info fail				2 red flags					
17 Ground speed info fail				2 red flags					
18 Transponder failure		1 amb lt						1 yel lt	
19 Transponder tests ok				1 grn lt					
20 VHF nav inoperative								2 red lts	
21 ILS receiver failure								2 amb lts	
22 Auto/manual tuning failure								2 wht lts	
23 VOR receiver in test mode	2 red lts	2 red lts							

25.1331(a) For each instrument required by paragraph 25.1302(b) that uses a power supply, the following apply: (1) Each instrument must have a visual means integral with, or adjacent to, the instrument, to indicate when power adequate to sustain proper instrument performance is not being supplied.



Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
24 Transponder in test mode	1 grn lts		1 grn lts						
25 Rising runway/localizer info fail							2 orn flags		2 ( ) shutters
26 DME receiver power fail	4 red flags (° 27)	4 red flags (° 27)				4 red flags (° 27)	2 striped orn flags	4 red flags	
27 DME data failure	4 red flags (° 26)	4 red flags (° 26)		4 red flags	2 red flags	4 red flags (° 26)	2 wht lines in place of digits (° 46)	4 red flags	
28 Localizer info fail	2 red flags (° 32)	2 red flags (° 32)	2 red flags (° 32)			2 red flags (° 32)			2 ( ) flags (° 32)
32 VOR info fail	2 red flags (° 28)	2 red flags (° 28)	2 red flags (° 28)	4 red flags		2 red flags (° 28)		2 red flags	2 ( ) flags (° 28)
33 Heading info fail		2 red flags		2 red flags		2 red flags	2 orn flags (° 9, 46)	2 red flags	
34 Glide slope info fail	2 red flags	2 red flags	2 red flags	2 red flags		4 red flags	4 orn flags		2 red flags
35 Weather radar mode annunciation	6 wht lts	6 wht lts						6 wht lts	
36 Weather radar antenna failure	1 amb lts	1 amb lts		1 amb lts				1 amb lts	
37 Weather radar receiver/transmitter failure	1 amb lts	1 amb lts		1 amb lts				1 amb lts	
40 Heading system using magnetic heading data							2 blk/whit flags	2 wht lts	
41 Heading system using gyro compass data without magnetic corrections				10 lts on 2 HSI's			2 blk/whit flags	2 wht lts	
42 Heading info sources				3 red lts					
45 INS out of tolerance				6 red lts			4 orn flags (° 9) & 2 red lts		
46 INS failure									
47 INS computer operating in nav mode				3 grn lts					
49 INS ready to accept remotely loaded waypoint data				3 amb lts					

121-APPENDIX G2. Equipment and equipment installation-Inertial Navigation Systems (INS) or Doppler Radar System. (c) The equipment must provide, by visual, mechanical or electrical output signals, indications of the invalidity of output data upon the occurrence of probable failures or malfunction within the system. 3. Equipment and equipment installation-Inertial Navigation Systems (INS). (d) The equipment must provide such visual, mechanical or electrical output signals as may be required to permit the flight crew to detect probable failures or malfunctions in the system.

Alerting function	Type of alert									Applicable federal aviation regulations (FAH)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
50 Waypoint alert				3 amb lts & 2 ( ) Lights on HSIs			4 amb lts			
51 INS on battery				6 amb lts			2 amb lts			
52 Doppler 10 mile staging alert	2 fl wht & 2 amb lts									
53 Rate of turn info fail							2 orn flags			
54 Clock power interrupter							3 red flags			121 - APPENDIX G3. Equipment and equipment installation - Inertial Navigation Systems (INS) (2) A display of alignment status or a ready to navigate light showing completed alignment to the flight crew.
55 INS alignment in progress							2 amb/grn dual legend lts (°56)			
56 INS ready for new mode							2 amb/grn dual legend lts (°55)			
57 INS battery power less than minimum							2 red lts			
58 Avionics failure								1 amb lt		
59 Doppler sensor failure	2 wht lts									

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	
1 Engine isolation valve off (closed)								3 wht lts	
2 Engine area overheat								3 amb lts	2 amb lts (*5,25,27)
3 Crossbleed valve off (closed)								2 wht lts	
4 Crossbleed area overheat								1 amb lt	
5 Duct overheat				4 amb lts	1 red lt			4 amb lts	2 amb lts (*2,25,27)
6 High pressure bleed valve closed								3 wht lts	
7 ATM isolation valve off (closed)								1 wht lt	
8 Pneumatic press hi and relief valve open				4 amb lts	4 amb lts	1 red band			
10 Bleed air valve closed				4 amb lts					
11 High stage bleed valve open				4 grn lts			3 amb lts		
13 Turbocompressor low oil press	3 amb lts								
14 Turbocompressor overspeed	3 amb lts								
15 Bleed air overheat/trip-off		2 amb lts							
16 Bleed air temp high		1 amb lt	2 amb lts		2 grn/red bands		4 red lts & 3 orn bands	6 red lts	
18 Bleed trip off			2 amb lts						
19 Dual bleed sources			1 amb lt						
20 Manifold failure					2 amb lts		4 red lts		
21 Abnormal pneumatic press					1 amb lt		3 amb lts & 3 yel/orn bands		
22 Isolation valve and switch positions disagree							2 amb lts		
23 Use engine pneumatic supply							1 amb lt		

Alerting function	Type of alert									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
24 APU isolation valve open							1 blu lt			
25 Pneumatic system failure							1 amb lt		2 amb lts ( * 2, 5, 27 )	
26 Supply duct failure								2 amb lts		
27 Bleed duct overpressure								1 amb lt	2 amb lts ( * 2, 5, 25 )	
28 Abnormal pneumatic air flow rate							3 wht bands			

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	721	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
Reverser in transit (for count down—DC 8)	4 blu lts	3 blu lts		4 blu lts	4 amb lts	2 blu ltr		3 grn lts	
Reverser operating	4 amb lts	3 amb lts		4 amb lts	4 amb lts	2 amb lts	3 grn lts	3 amb lts	
Reverser accumulator pressure low			1 amb lt			2 amb lts			
No. 2 engine failure								2 amb lts	
N2 overspeed	4 grn/red bands	3 grn/yel/red bands	2 grn/yel/red bands	4 amb lts	4 red bands	2 red bands	3 orn bands & 3 orn pointers	3 red flags	
N1 overspeed	4 grn/red bands	3 grn/yel/red bands	2 grn/yel/red bands	4 amb lts	4 red bands	2 red bands	3 orn bands & 3 orn pointers	3 amb lts	
TGT overtemp								3 fl (for 5 seconds, then steady red lts	
Ignition systems off				4 blu/wht lts					
N3 overspeed								3 amb lts	
Maximum indications on engine instruments reset								1 wht lt	
EPR indication fail			1 red flag					3 red flags	
Loss of power to any engine instrument channel				20 red barber pole flags				15 red/wht barber pole flags	
EGT overtemp	4 grn/yel/red bands	3 grn/yel/red bands	2 grn/yel/red bands	4 amb lts & 4 fl/steady red lts	4 yel/red bands	2 yel/red bands	3 amb lts, 3 yel/orn bands & 3 orn pointers		
Continuous ignition on								1 wht lt	
Ground start switch pressed and N3 < 51%								1 amb lt	

25.1549 For each required power plant instrument, as appropriate to the type of instrument, (a) Each maximum and, if applicable, minimum safe operating limit must be marked with a red radial or red horizontal line; (b) Each normal operating range must be marked with a green arc or green vertical line, not extending beyond the maximum and minimum safe limits; (c) Each takeoff and precautionary range must be marked with a yellow arc or yellow vertical line; and (d) Each engine or propeller range that is restricted because of excessive vibration stresses must be marked with red arcs or red vertical lines.

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
Ground start valve open		3 amb lts		4 grn lts		2 amb lts		3 grn lts	
Flight start system on				4 blu/wht lts				3 amb lts	
EPB mode selected				6 wht lts			5 blu lts	4 wht lts & 1 flag	
N1 or N2 indicator failure off							6 blk/orn flags		
Excessive engine vibration								3 amb lts	2 wht lts
Vibration pickup selection								2 wht lts	
Oil pressure indicator in test mode								1 wht lt	
Oil temperatures high	4 grn & 4 red bands	3 grn/yel/red bands	2 grn/yel/red bands	4 yel bands	4 grn/yel/red bands	2 yel/red bands	3 yel/orn bands		
Ground start system on				4 blu/wht lts					
Ignition system(s) on	1 amb lt			1 grn lt	4 blu lts		3 amb lts		4 amb lts
Fuel filter pressure drop						2 amb lts	3 amb lts		
Engine fail		2 amb lts					2 amb lts		
Oil filter clogged	4 amb lts	3 red lts	2 amb lts	4 amb lts		2 amb lts	3 amb lts	3 amb lts	
Engine oil pressure low	4 amb lts & 4 grn bands	3 amb lts & 3 grn/yel/red bands	2 amb lts & 2 grn/yel/red bands	4 amb lts & 4 yel bands	4 amb lts & 4 grn/yel/red bands	2 amb lts & 2 grn/yel/red bands	3 amb lts	3 fl amb lts	2 red lts
Ground idle relay in ground idle mode				1 amb lt					
Water injection pump pressurized				4 grn lts					
Loss of water injection pump pressure				1 amb lt					

25.1305(c) For turbine engine-powered airplanes. In addition to the powerplant instruments required by paragraph (a) of this section, the following powerplant instruments are required: (1) A warning means for the oil strainer or filter required by Section 25.1019, if it has no bypass to warn the pilot of the occurrence of contamination of the strainer or filter screen before it reaches the capacity established in accordance with Section 25.1019(a) (2)

25.1305 The following are required powerplant instruments: For all airplanes. (5) An oil pressure warning means for each engine, or a master warning means for all engines with provision for isolating the individual warning means from the master warning means.

Alerting function	Type of alert									Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111	
Water injection/flow to engine on				4 grn lts						25.1305(f) For airplanes equipped with fluid augmentation systems (other than fuel), an approved means must be provided to indicate the proper functioning of that system to the flight crew.
Engine 2 failure monitor armed								1 grn lt		
Reverser unlocked			2 amb lts				3 amb lts		2 amb lts	
Reverser armed			1 blu lt							
N1 (EPR) limit data unusable				1 yel flag			1 blk/orn flag			
EGT info (on/off)							3 blk/orn flags			
Engine oil pressure abnormal							3 yel/grn/orn bands			
Reverser valve open							3 amb lts			
Engine low pressure shaft rotation									1 variable rate fl grn lt	
Engine/APU malfunction								1 fl amb lt		
Ground cooling & blowaway jet shut off					1 blu lt					

25.1305(f) For airplanes equipped with fluid augmentation systems (other than fuel), an approved means must be provided to indicate the proper functioning of that system to the flight crew.

Alerting function	Type of alert								Applicable federal aviation regulations (FAR)
	707/720	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
Gross weight indication selected								1 wht lt	
Center of gravity indication selected								1 wht lt	
Center of gravity at forward or aft limit				1 amb lt				2 amb lts	
Weight and balance system power on				1 wht lt				1 wht lt	
Weight and balance system in test mode								1 wht lt	
Hard landing								3 red & 3 amb lts	
Weight and balance system operational status				1 gm & 2 amb lts					
Hard landing indications reset								1 wht lt	



## **APPENDIX B**

### **DETAILED DATA USED IN ALERTING FUNCTION AND CHARACTERISTICS ANALYSES**

**Table B-1 Operational Distribution of Visual Alerting Functions**

ALERT CLASSIFICATION	AIRCRAFT TYPE								
	707	727	737	747	DC-8	DC-9	DC-10	L-1011*	BAC-111
WARNING	70	69	49	109	85	81	127	118	39
CAUTION	118	197	153	346	87	123	291	385	44
ADVISORY/STATUS	105	103	115	302	59	40	208	295	13
TOTAL	293	369	317	757	231	244	626	798	96

\*L-1011 utilizes lighted pushbutton switches, with color modes to indicate switch state, instead of toggle switches.

**Table B-2 Percentage Distribution of Visual Alerting Functions Among Operational Classifications**

ALERT CLASSIFICATION	AIRCRAFT TYPE								
	707	727	737	747	DC-8	DC-9	DC-10	L-1011*	BAC-111
WARNING	24%	19%	16%	14%	37%	33%	20%	15%	41%
CAUTION	40%	53%	48%	46%	38%	50%	47%	48%	46%
ADVISORY/STATUS	36%	28%	38%	40%	25%	16%	33%	37%	13%

\*L-1011 utilizes lighted pushbutton switches, with color modes to indicate switch state, instead of toggle switches.

**Table B-3 Color Distribution of Warning/Caution/Advisory Alerts**

ALERT TYPE	AIRCRAFT TYPE								
	707	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
<b>LIGHTS</b>									
RED	31	25	15	45	22	25	45	43	33
AMBER OR YELLOW	110	172	134	315	59	109	235	352	44
BLUE	33	20	25	90	35	25	45	17	2
GREEN	21	39	55	115	3	4	53	40	7
WHITE	15	20	2	55	2	2	41	177	4
<b>FLAGS</b>									
RED	20	24	15	55	15	25	44	75	5
AMBER OR YELLOW	1	3	0	5	2	2	3	15	0
GREEN	0	0	2	0	0	0	0	0	0
WHITE	13	5	4	3	0	1	5	37	0
BLACK	0	0	0	0	0	0	0	22	0
<b>BANDS</b>									
RED	19	20	15	5	44	25	35	0	0
AMBER OR YELLOW	7	22	15	24	15	12	53	5	0
GREEN	23	15	13	5	15	7	5	2	0
WHITE	0	0	0	0	0	0	13	0	0
<b>AURAL</b>	13	15	13	17	10	15	14	15	9

**Table B-4 Number of Visual Alerts Which Also Activate an Aural Alert**

ALERT TYPE	NUMBER OF ALERTS PER AIRCRAFT								
	707	727	737	747	DC-8	DC-9	DC-10	L-1011	BAC-111
RED LIGHTS OR FLAGS	8	10	14	20	8	10	16	14	4
AMBER AND YELLOW LIGHTS OR FLAGS	11	19	16	7	2	7	7	10	1
BLUE LIGHTS OR FLAGS	3	1	2	3	3	1	8	1	0
GREEN LIGHTS OR FLAGS	0	0	2	0	0	0	0	0	0
WHITE/CLEAR LIGHTS OR FLAGS	0	0	0	2	0	0	7	0	0

**APPENDIX C**  
**COCKPIT NOISE DATA**

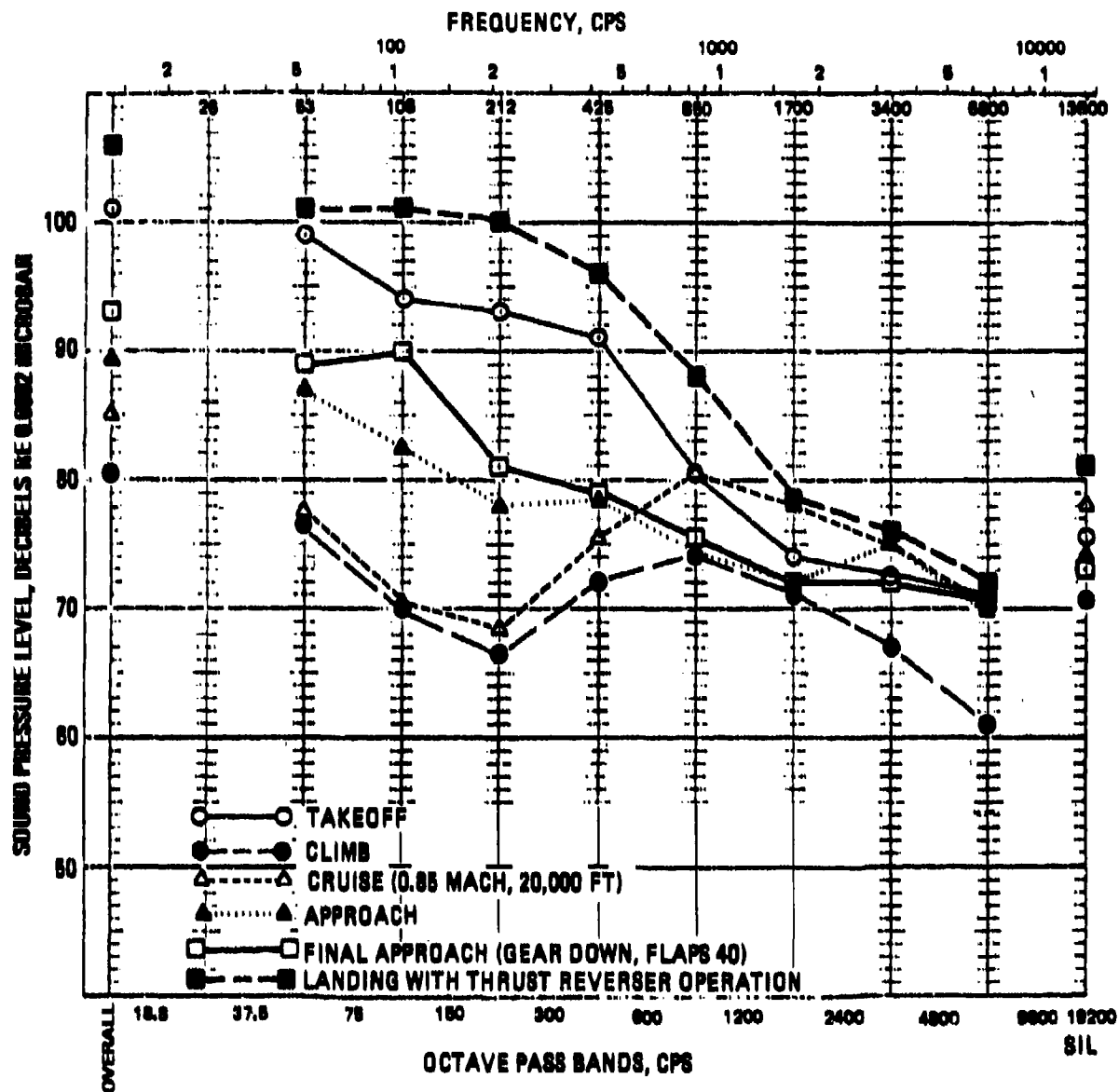


Figure C-1 Maximum Cockpit Noise Levels During Various Flight Operations For 707-320B/C Aircraft

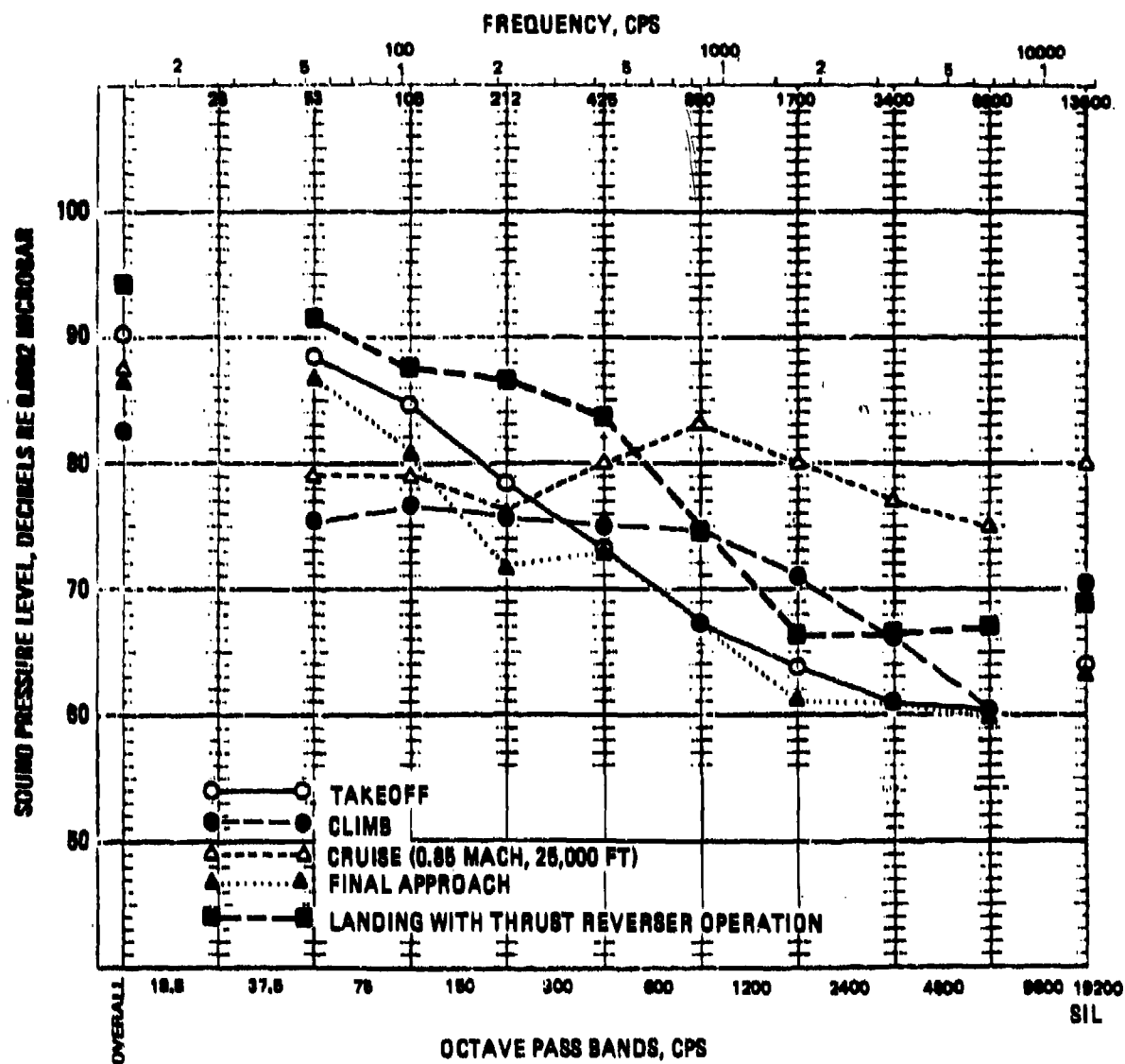


Figure C-2 Maximum Cockpit Noise Levels During Various Flight Operations For 727-100/200 Aircraft



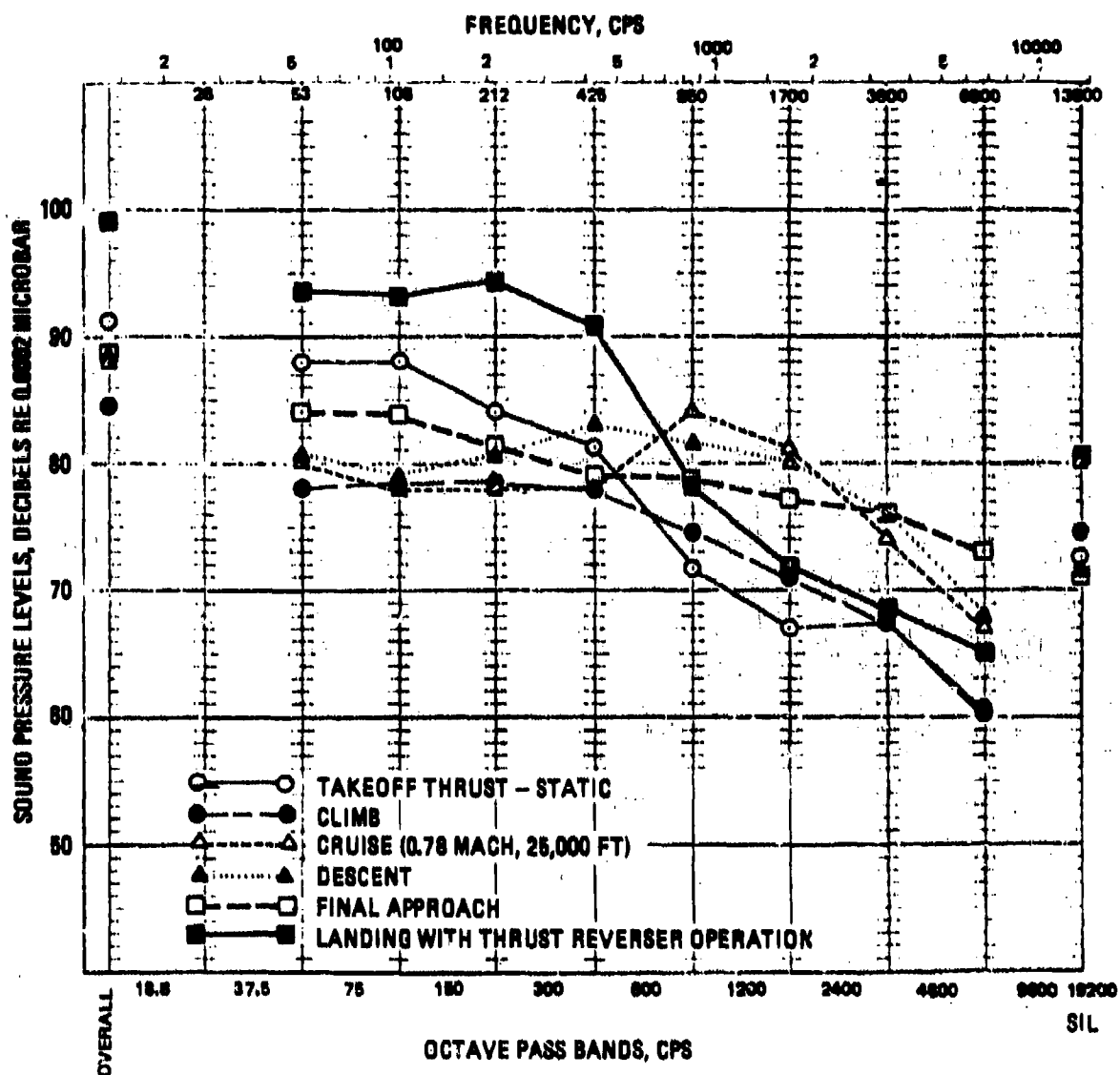
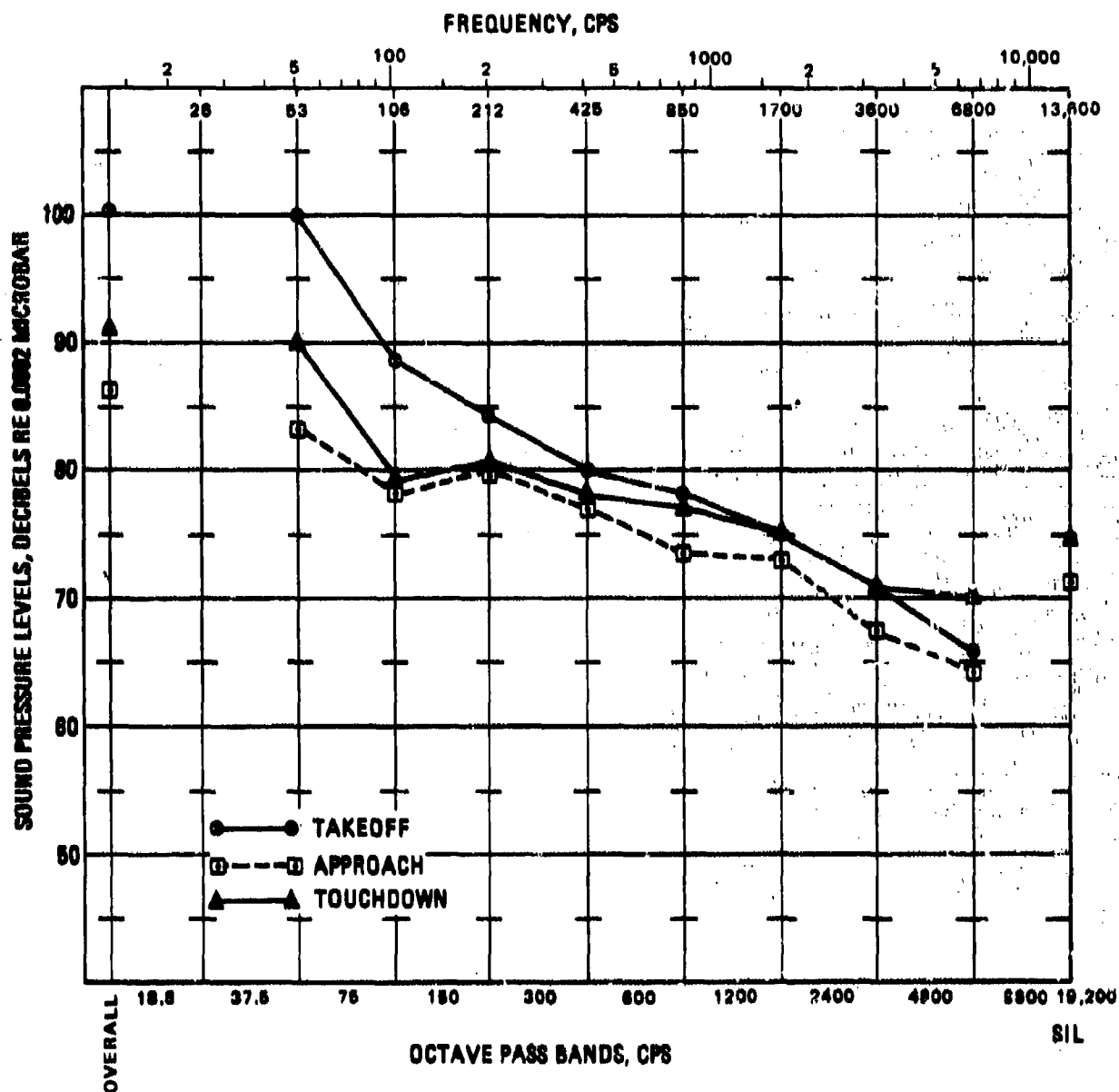
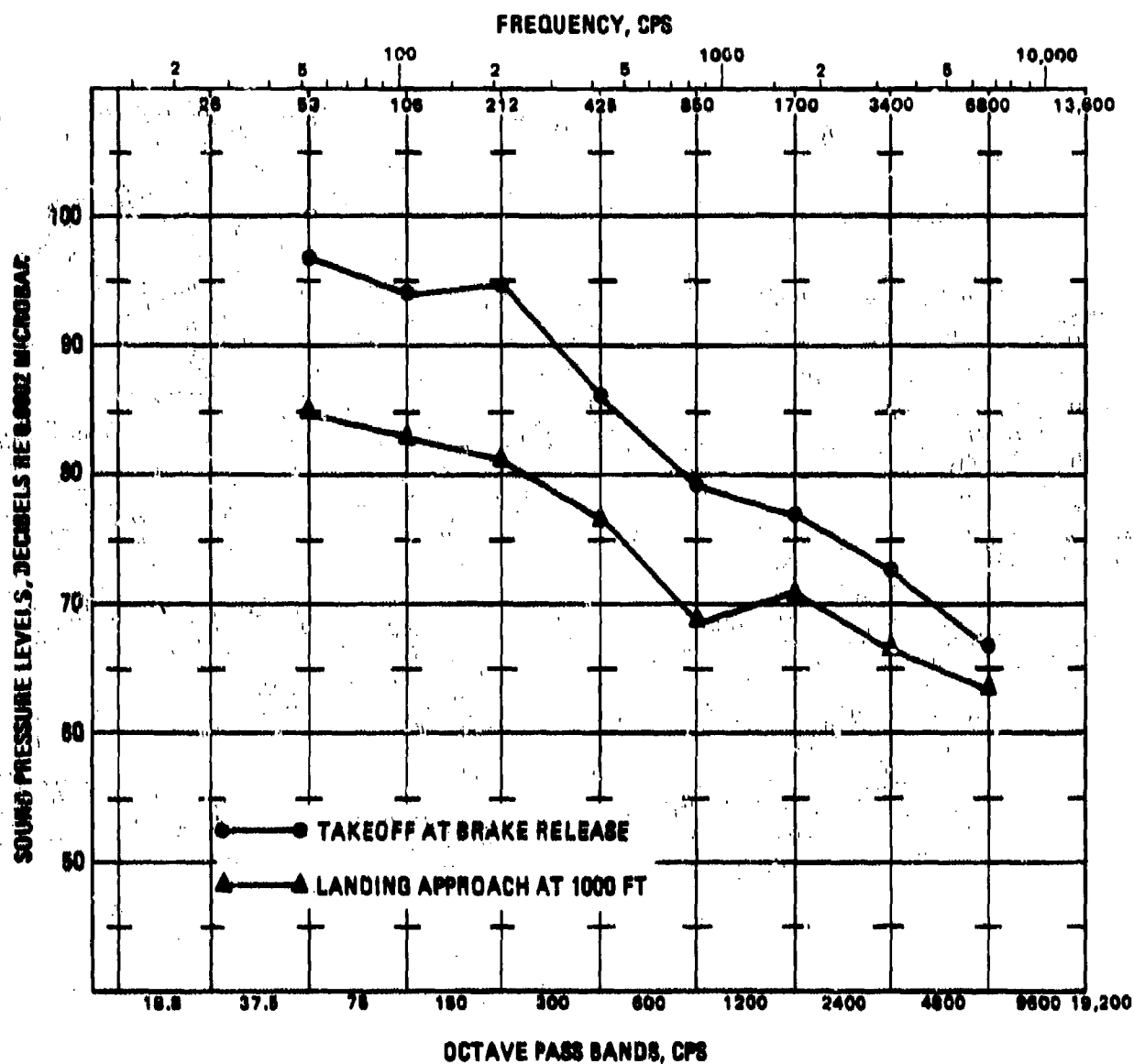


Figure C-3 Maximum Cockpit Noise Levels During Various Flight Operations For 737-200 Aircraft

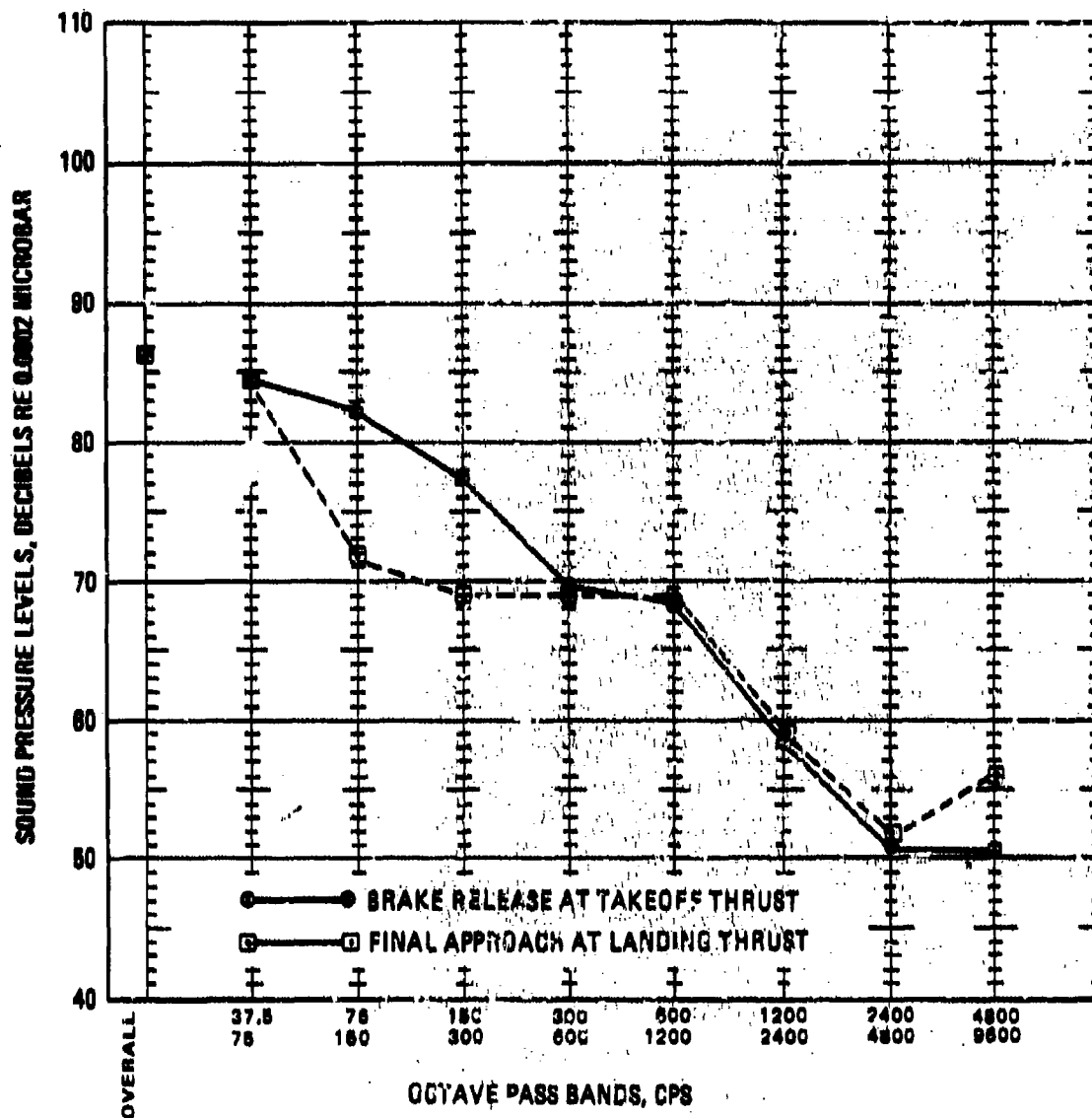


**Figure C-4 Maximum Cockpit Noise Levels During Various Flight Conditions For 747-100 Aircraft**

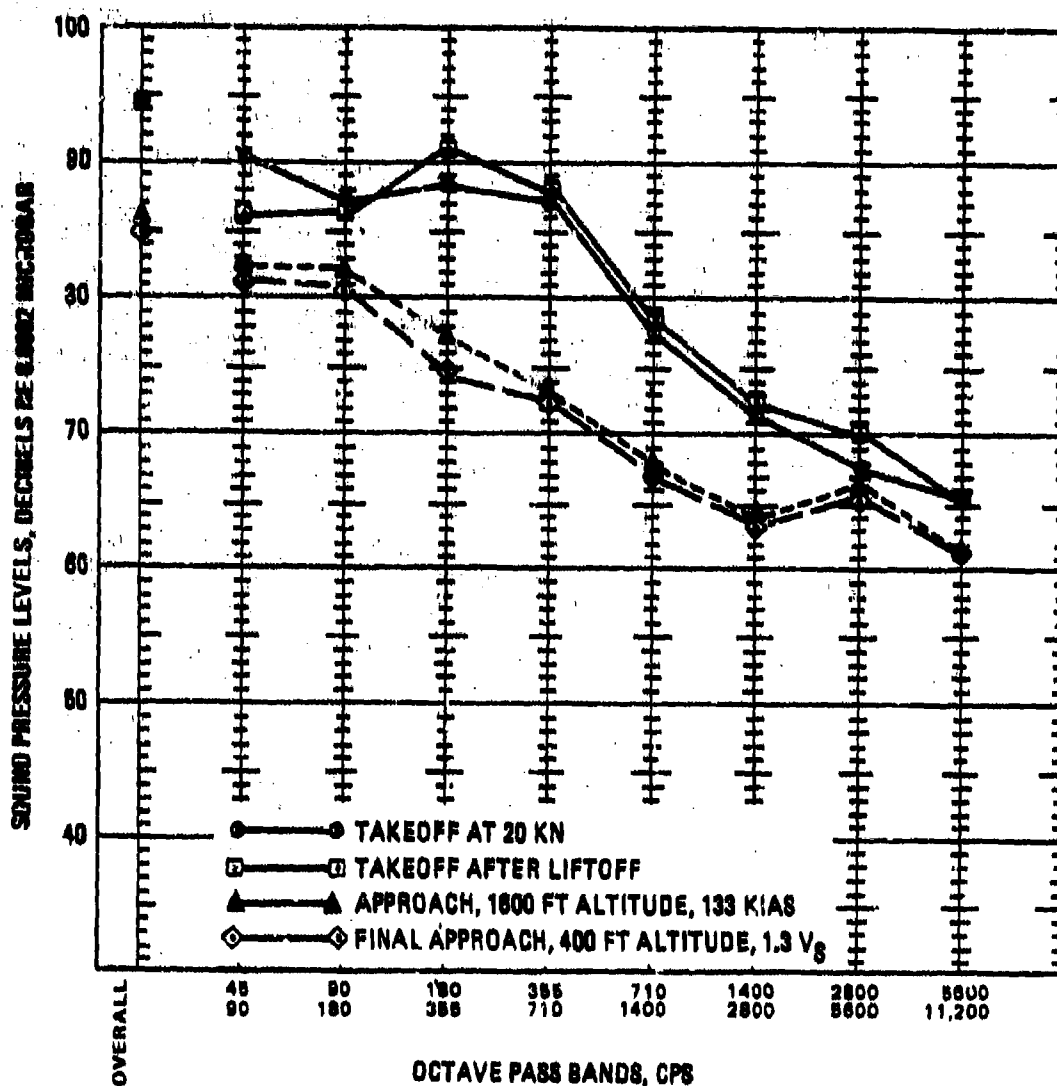


NOTE: NOISE LEVELS MEASURED BETWEEN PILOT AND COPILOT—40 INCHES ABOVE FLOOR

Figure C-5 Maximum Cockpit Noise Levels During Various Flight Conditions for DC-8-63 Aircraft

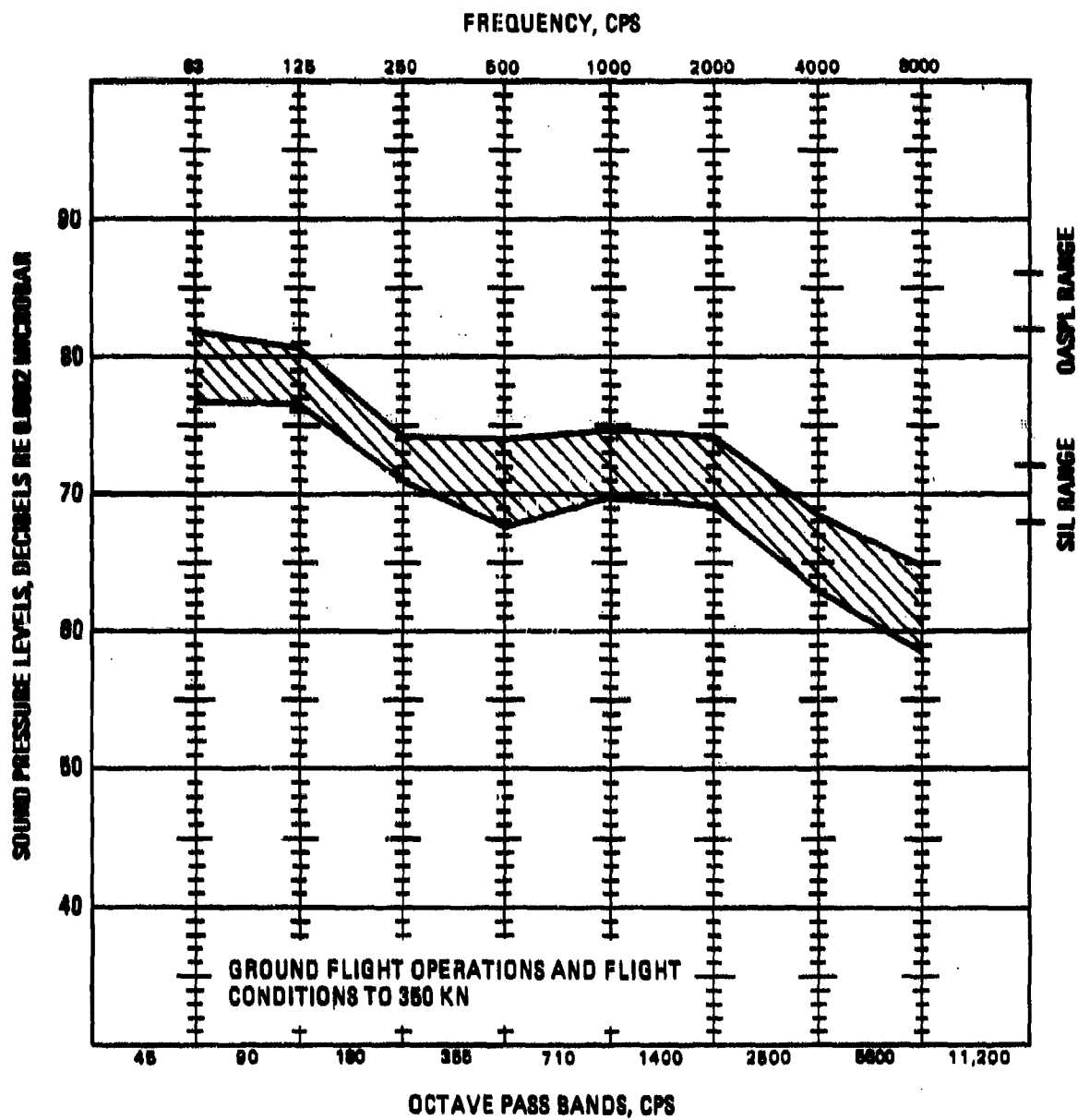


**Figure C-6 Estimated Cockpit Noise Levels During Various Flight Conditions For DC-9-30 Aircraft**



NOTE: SOUND PRESSURE LEVELS MEASURED 40 INCHES ABOVE FLOOR  
BETWEEN PILOT AND COPILOT

Figure C-7 Cockpit Noise Levels During Various Flight Conditions for  
DC-10-30 Aircraft



**Figure C-8 Cockpit Noise Levels During Various Flight Operations For L-1011 Aircraft**

## APPENDIX D

### TABULATIONS OF FUNCTIONAL DISTRIBUTION OF ALERTS ON EACH BASIC TYPE OF AIRCRAFT

**Table D-1 Functional Distribution of Warning/Caution/Advisory Alerts For 707 Aircraft**

SYSTEM CLASSIFICATIONS	AURAL	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG
AIR CONDITIONING	1				6			3		2			
AIRCRAFT GENERAL		1F			8								
ALTITUDE ALERT SYSTEM	1	1F	1		1			1					
APU													
APCS		2F			1F+2			2					
COMMUNICATIONS	2	3			5			1	1				
ELECTRICAL		5			17				2	2			
EMERGENCY EQUIPMENT	1	1F			1								3
FIRE PROTECTION	1	6			4			4					4
FLIGHT CONTROLS	2	2		1	2		1	2			2		
FLIGHT INSTRUMENTATION AND AIR DATA	4	2F	3		11	1			3	1			2
FUEL					16				16				
HYDRAULIC		1		2	8		2				1		
ICE AND RAIN PROTECTION					4			4	7				
LANDING GEAR AND BRAKES	1	3			1			3					4
NAVIGATION		2F+2	16		4			1		2F+8			
PNEUMATICS					6								
POWER PLANT				16	13		4		4		20		
WEIGHT AND BALANCE													

NOTE: ( ) F denotes flashing light.  
1 light of undefined nature not included in listing above



**Table D-2 Functional Distribution of Warning/Caution/Advisory Alerts For 727 Aircraft**

SYSTEM CLASSIFICATIONS	AURALS	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG
AIR CONDITIONING	1				9			1					
AIRCRAFT GENERAL		1F			14			1					
ALTITUDE ALERT SYSTEM	1	1F	1		1			1					
APU				1	2		1				1		
APCS		2F			1F+2			4					
COMMUNICATIONS	2				3			4	1	9			
ELECTRICAL		1			31		3			2F+1			
EMERGENCY EQUIPMENT	1	1F			2								3
FIRE PROTECTION	1	2F+8			11								
FLIGHT CONTROLS	3				27	2		15					
FLIGHT INSTRUMENTATION AND AIR DATA	5	2F	5		21	1			2	2			2
FUEL					11				12				
HYDRAULIC				2	8		2	1			2		
ICE AND RAIN PROTECTION					6			9	2				
LANDING GEAR AND BRAKES	1	5		2	6		1	3			1		
NAVIGATION		2	18		3					5			
PNEUMATICS					3								
POWER PLANT		3		15	11		15		3		15		
WEIGHT AND BALANCE													

NOTE: ( ) F denotes flashing light.  
8 flags of undefined nature not included in listing above.

**Table D-3 Functional Distribution of Warning/Caution/Advisory Alerts for 737 Aircraft**

SYSTEM CLASSIFICATIONS	AURAL	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG
AIR CONDITIONING	1			1	8		1	2	3				
AIRCRAFT GENERAL					14								
ALTITUDE ALERT SYSTEM	1		1						1				
APU				1	4		1		1		1		
AFCs		2F			8			10					
COMMUNICATIONS	2							23	1				
ELECTRICAL					10		4		4				
EMERGENCY EQUIPMENT					2								3
FIRE PROTECTION	1	8			7			3					
FLIGHT CONTROLS	2				21			18					
FLIGHT INSTRUMENTATION AND AIR DATA	5	2	4		2F+19				2F	2F		2	
FUEL					9				5				
HYDRAULIC				1	9		2				1		
ICE AND RAIN PROTECTION					5			11	8				
LANDING GEAR AND BRAKES	1	4		2	4		1	3			1		
NAVIGATION			12					1					1
PNEUMATICS					5								
POWER PLANT			1	10	7		10		1		10		
WEIGHT AND BALANCE													

NOTE: ( 1F denotes flashing light.

**Table D-4 Functional Distribution of Warning/Caution/Advisory Alerts For 747 Aircraft**

SYSTEM CLASSIFICATIONS	AURALS	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG
AIR CONDITIONING	1				14			1	6	6	1		
AIRCRAFT GENERAL	1				17				3	3			
ALTITUDE ALERT SYSTEM	1	2			1			1					
APU					1			1	2				
APCS	1	4F+2			2F+20			23					
COMMUNICATIONS	2				2			7	1F+2	22			
ELECTRICAL					58		8	7	15	17			
EMERGENCY EQUIPMENT	1	1F			2								3
FIRE PROTECTION	1	12		4	15		4	8	11				
FLIGHT CONTROLS	2				34			18		1			
FLIGHT INSTRUMENTATION AND AIR DATA	8	4F	10		15	1			2	2			
FUEL					19	4			17	9			
HYDRAULIC					20				4		4		
ICE AND RAIN PROTECTION					7			20	5	3			
LANDING GEAR AND BRAKES	1	3		4	34		4	8	6	6			
NAVIGATION		9	25		14			4					
PNEUMATICS					12			4					
POWER PLANT		4F+4	20		26	1	8	13	16	18			
WEIGHT AND BALANCE					3			1		1			

NOTE: ( ) F denotes flashing light.  
 5 flags and 12 lights of undefined nature not included in listing above.

Table D-5 Functional Distribution of Warning/Caution/Advisory Alerts for DC-8 Aircraft

SYSTEM CLASSIFICATIONS	AURALS	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG
AIR CONDITIONING	1	4		12	3				2		4		
AIRCRAFT GENERAL		3			1				3				
ALTITUDE ALERT SYSTEM	1		1		2								
APU													
APCS		2			3				1				
COMMUNICATIONS	2								12				
ELECTRICAL		2			13				1				
EMERGENCY EQUIPMENT					1								
FIRE PROTECTION	1	6		4	4		4						
FLIGHT CONTROLS	2				4				2				
FLIGHT INSTRUMENTATION AND AIR DATA	2	3	8		5				2	2			
FUEL				4	6				8		4		
HYDRAULIC				1	2				1				
ICE AND RAIN PROTECTION					5								
LANDING GEAR AND BRAKES	1	1		1	1			3					
NAVIGATION			10			2							
PNEUMATICS		1		2	7						2		
POWER PLANT				20	12		12		4		8		
WEIGHT AND BALANCE													

NOTE: ( ) IF denotes flashing light.  
 8 lights of undefined nature not included in listing above

**Table D-6 Functional Distribution of Warning/Caution/Advisory Alerts For DC-9 Aircraft**

SYSTEM CLASSIFICATIONS	AURALS	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG
AIR CONDITIONING	1	2		2	3								
AIRCRAFT GENERAL		2			10								
ALTITUDE ALERT SYSTEM	1	1	1		1			1					
APU				2	2		2				1		
APOS	1	1F+1											
COMMUNICATIONS	2	2			2				2				
ELECTRICAL		2		2	13		2		10	1			
EMERGENCY EQUIPMENT	1	1F			1				1				1
FIRE PROTECTION	1	3		2	9		2						
FLIGHT CONTROLS	2	2F+2			6				2				
FLIGHT INSTRUMENTATION AND AIR DATA	5	2	8	4	20	2			1	1			
FUEL					6				2				
HYDRAULIC			2		4						2		
ICE AND RAIN PROTECTION					10				6				
LANDING GEAR AND BRAKES	1	7		2	10			3			2		
NAVIGATION			20										
PNEUMATICS				1									
POWER PLANT				10	12		6		2		2		
WEIGHT AND BALANCE													

NOTE: ( ) F denotes flashing light.  
2 flags of undefined nature not included in listing above.

Table D-7 Functional Distribution of Warning/Caution/Advisory Alerts for DC-10 Aircraft

SYSTEM CLASSIFICATIONS	AURALS	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	WHITE FLAG	WHITE BAND
AIR CONDITIONING	1	2		2	10		2		2				
AIRCRAFT GENERAL		3			24		1			2			1
ALTITUDE ALERT SYSTEM	1				1F+1								
APU				3	3		2		3				2
APCS	1	8F			40			76		10			
COMMUNICATIONS	2	3						4	9	26			
ELECTRICAL		5		4	26		16	4	12	2	3		3
EMERGENCY EQUIPMENT	1	1F			1			1					2
FIRE PROTECTION	1	6		3	18		3						
FLIGHT CONTROLS	2		1		1F+9	1			5				
FLIGHT INSTRUMENTATION AND AIR DATA	5	2	13		8	2			2	2			
FUEL					1F+20				3				
HYDRAULIC				3	16		9		4				
ICE AND RAIN PROTECTION					8				3				
LANDING GEAR AND BRAKES	1	3		2	6		2	3					2
NAVIGATION		4	20		9			2				8	
PNEUMATICS		8		6	10		3		1				3
POWER PLANT			10	16	23		15	3	5		3		
WEIGHT AND BALANCE													

NOTE: ( ) F denotes flashing light.

**Table D-8 Functional Distribution of Warning/Caution/Advisory Alerts for L-1011 Aircraft**

SYSTEM CLASSIFICATIONS	AURAL	WARNINGS			CAUTIONS			ADVISORY/STATUS						
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG	BLACK FLAG
AIR CONDITIONING	1				1F+24					18	2			
AIRCRAFT GENERAL					1F+20					13				
ALTITUDE ALERT SYSTEM	1	2F	2		2			2						
APU			4		11					1				
APCS	1		8		3F					9			36	22
COMMUNICATIONS	2				4			6	2	19				
ELECTRICAL		1F+5			1F+33		3	1		5				
EMERGENCY EQUIPMENT	1	1F			2			1					1	
FIRE PROTECTION	2	4F+9			4F+33					2				
FLIGHT CONTROLS	2	1			7F+40	2		15		39				
FLIGHT INSTRUMENTATION AND AIR DATA	4	2	17		21	16			2	2				
FUEL					26				13	6				
HYDRAULIC					2F+25			1		12				
ICE AND RAIN PROTECTION					3F+30			3		16				
LANDING GEAR AND BRAKES	1	4	1		3F+18		2	4						
NAVIGATION		2	26		1F+6					12				
PNEUMATICS		6			11					9				
POWER PLANT		3F	17		4F+21			7		9				
WEIGHT AND BALANCE		3			5					5				

NOTE ( 1F denotes flashing light)

Table D-9 Functional Distribution of Warning/Caution/Advisory Alerts for 6AC-111 Aircraft

SYSTEM CLASSIFICATION	AURALS	WARNINGS			CAUTIONS			ADVISORY/STATUS					
		RED LIGHT	RED FLAG	RED BAND	AMBER/YELLOW LIGHT	AMBER/YELLOW FLAG	AMBER/YELLOW BAND	GREEN LIGHT	BLUE LIGHT	WHITE LIGHT	GREEN BAND	GREEN FLAG	WHITE FLAG
AIR CONDITIONING		1			3								
AIRCRAFT GENERAL		2F+5											
ALTITUDE ALERT SYSTEM	1												
APU			(2 LIGHTS)										
APCS					1F		(6 FLAGS)						
COMMUNICATIONS	1				2								
ELECTRICAL		3			8								
EMERGENCY EQUIPMENT													
FIRE PROTECTION	1	5											
FLIGHT CONTROLS	3	9			7			1					
FLIGHT INSTRUMENTATION AND AIR DATA	2				2F				2F	2F			
FUEL		2			2								
HYDRAULIC		3			3								
ICE AND RAIN PROTECTION					8								
LANDING GEAR AND BRAKES	1	1						4					
NAVIGATION			6										
PNEUMATICS					2								
POWER PLANT		2			6			2F		2			
WEIGHT AND BALANCE													

NOTE: 1 1F denotes flashing light.  
3 lights and 12 flags of undefined nature not included in listing above.



## **APPENDIX E**

### **SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS FOUND IN SAE, MILITARY, AND RTCA STANDARDS**

# **TABLE E-1** **ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 450**

## **2. FLIGHT DECK SIGNALS**

### **2.1 GENERAL PHILOSOPHY: AIRCRAFT FLIGHT DECK SIGNAL SYSTEMS MAY CONSIST OF ONE OR MORE OF THE SIGNALS HEREIN DEFINED.**

INSOFAR AS IS TECHNICALLY FEASIBLE, IT IS DESIRABLE TO PREVENT WARNING OR CAUTION SIGNALS FROM EXISTING OR OCCURRING WHEN NOT APPLICABLE IN VIEW OF THE BASIC INTENT OR DESIGN AIM OF THE SIGNAL SYSTEM. THIS DESIGN PHILOSOPHY IS DESIRABLE IN ORDER TO PREVENT A BUILD-UP OF FLIGHT CREW TOLERANCE AND DISREGARD FOR THE SIGNAL.

IF THE PRIME FUNCTION OF A MASTER VISUAL SIGNAL, OR OF ONE OF THE VISUAL SIGNALS IN AN ANNUNCIATOR PANEL, IS TO DIRECT ATTENTION TO AN INDICATOR OR CONTROL DEVICE, IT SHALL SUPPLEMENT A SEPARATE VISUAL SIGNAL AT THAT LOCATION. THE INDIVIDUAL VISUAL SIGNALS USED WITH MASTER WARNING SIGNALS, MASTER CAUTION SIGNALS OR ANNUNCIATOR PANELS, SHOULD BE IDENTIFIED WITH TRANSILLUMINATED NOMENCLATURE.

SIGNALS SHOULD BE OF LIMITED INTENSITY SO THAT ATTENTION IS NOT DRAWN MORE TO THE NOISE OR LIGHT THAN IT IS TO THE SITUATION WHICH IS CAUSING THE SIGNAL. OVERWHELMING SIGNALS SHOULD BE AVOIDED SINCE THEY INTERFERE WITH CREW COORDINATION AND COMMUNICATION AND MAY ALARM A CREW MEMBER ENOUGH TO REDUCE HIS EFFICIENCY IN AN EMERGENCY SITUATION.

#### **2.1.1 VISUAL SIGNALS: MAY CONSIST OF LIGHTS (WITH OR WITHOUT TRANSILLUMINATED NOMENCLATURE), WARNING FLAGS OR INDICATORS, OR, IN THE CASE OF INSTRUMENT INDICATIONS, IN THE TOTAL REMOVAL OF THE PERTINENT INSTRUMENT DISPLAY.**

##### **2.1.1.1 MASTER WARNING LIGHT(S): A MASTER WARNING LIGHT IS A LIGHT WHICH IS USED WHERE WARNING LIGHTS ARE LOCATED OUTSIDE OF THE DIRECT VISION OF EITHER PILOT.**

**NOTE:** A MASTER WARNING LIGHT OR LIGHTS MAY BE REQUIRED BECAUSE OF THE LIMITATIONS OF VISIBILITY OF COLORED LIGHTS AND THE VARIABILITY OF LIGHTING CONDITIONS IN THE FLIGHT DECK.

##### **2.1.1.2 WARNING LIGHTS: LIGHTS PROVIDED TO WARN THE CREWMEMBER, OR THE CREW, OF A CONDITION WHICH REQUIRES IMMEDIATE PROTECTIVE OR CORRECTIVE ACTION.**

##### **2.1.1.3 MASTER CAUTION LIGHT(S): A MASTER CAUTION LIGHT IS A LIGHT WHICH IS USED WHERE CAUTION LIGHTS ARE LOCATED OUTSIDE OF THE NORMAL FIELD OF VISION OF EITHER PILOT.**

##### **2.1.1.4 CAUTION LIGHTS: LIGHTS PROVIDED TO INDICATE MALFUNCTIONS WHICH DO NOT REQUIRE IMMEDIATE ACTION, BUT WHICH MAY HAVE A SUBSEQUENT SIGNIFICANT EFFECT ON THE OPERATION OF THE AIRCRAFT.**

##### **2.1.1.5 ADVISORY LIGHTS: LIGHTS PROVIDED TO INDICATE SAFE OR NORMAL CONFIGURATION, CONDITION OF PERFORMANCE, OPERATION OF ESSENTIAL EQUIPMENT, OR FOR ATTRACTING ATTENTION FOR ROUTINE PURPOSES.**

##### **2.1.1.7 WARNING FLAGS OR INDICATORS: MECHANICALLY OR ELECTRICALLY ACTUATED DISPLAYS USED TO WARN OF AN UNSAFE SETTING OR MALFUNCTION OF INSTRUMENTS OR MECHANICAL DEVICES.**

#### **2.1.2 AUDIBLE SIGNALS: IF ONE AUDIBLE SIGNAL IS USED FOR MORE THAN ONE FUNCTION, IT SHALL BE ACCOMPANIED BY VISUAL SIGNALS WHICH WILL INDICATE THE MALFUNCTION WHICH IS CAUSING THE AUDIBLE SIGNAL.**

##### **2.1.2.1 WARNING BELL: A BELL WHICH OPERATES IN CONJUNCTION WITH A WARNING LIGHT ONLY TO INDICATE THE EXISTENCE OF A FIRE.**

##### **2.1.2.2 WARNING HORN: A HORN WHICH OPERATES TO INDICATE AN UNSAFE CONFIGURATION.**

**TABLE E-1 (CONT)**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 450**

- 2.1.2.3 **WARNING GONG:** A SINGLE BEAT SOUND USED TO WARN OF AN UNSAFE FLIGHT CONDITION OR INDICATION.
- 2.1.2.4 **WARNING "CRICKET":** A DEVICE WHICH GENERATES A CRICKET-LIKE SOUND TO WARN OF SPEEDS IN EXCESS OF  $V_{MO}$  -  $M_{MO}$ .
- 2.1.2.5 **CHIMES:** USED IN CONJUNCTION WITH COMMUNICATION SYSTEMS OF THE AIRCRAFT. FOR EXAMPLE: CABIN 10-FLIGHT DECK; SELCAL, ETC.
- 2.1.2.6 **TONE:** AN 800-CYCLE THREE-NOTE CORD OF INCREASING AMPLITUDE USED TO INDICATE APPROACHING THE DECISION HEIGHT AND CUTTING OFF WHEN REACHING DECISION HEIGHT.
- 2.1.3.1 **STICK-SHAKER:** A DEVICE WHICH CAUSES THE PILOT'S CONTROL WHEEL TO VIBRATE TO WARN OF APPROACHING TO, OR OF OPERATION IN, A STALLED CONDITION.
- 2.1.3.2 **FOOT-THUMPER:** A DEVICE WHICH VIBRATES THE PILOTS FOOT ON THE BRAKE PEDAL TO INDICATE THE CYCLING OF THE ANTI-SKID SYSTEM, OR TO WARN OF WHEEL SKIDDING.
- 2.2.1.1 **STEADY MASTER WARNING LIGHT:** THE STEADY MASTER WARNING LIGHT SHALL BE USED EXCLUSIVELY TO WARN OF FIRE AND WILL BE ACCOMPANIED BY THE WARNING BELL.
- 2.2.1.2 **FLASHING MASTER WARNING LIGHT:** THE FLASHING MASTER WARNING LIGHT SHALL BE USED TO INDICATE AN UNSAFE CONDITION OTHER THAN FIRE.
- 2.2.1.3 **LOCATION:** THE MASTER WARNING LIGHT, OR LIGHTS, AND THE MASTER CAUTION LIGHT, WILL BE LOCATED NEAR THE CENTER LINE OF THE AIRCRAFT NEAR THE TOP OF THE CENTER INSTRUMENT PANEL.
- 2.2.2.1 **WARNING, CAUTION AND ADVISORY LIGHTS:** AN INDEPENDENT LIGHT SYSTEM SHALL BE PROVIDED FOR EACH INDIVIDUAL FUNCTION OR SYSTEM TO BE MONITORED. WHERE A MASTER WARNING LIGHT IS REQUIRED, IT WILL SUPPLEMENT A SPECIFIC STEADY WARNING LIGHT AT THE INDICATOR OR CONTROL OF THE AREA OR EQUIPMENT AFFECTED.
- 2.2.2.2 **WARNING LIGHTS SHALL BE WITHIN THE CONTROL DEVICE, OR SHALL BE LOCATED IN CLOSE PROXIMITY TO THE INDICATOR OR CONTROL DEVICE, WHERE ATTENTION TO THE INDICATOR OR CONTROL DEVICE IS THE PRIME FUNCTION OF THE WARNING SIGNAL.**
- 2.2.2.4 **THE WARNING LIGHTS FOR THE FOLLOWING SPECIFIC INDICATORS OR CONTROL DEVICES WILL BE LOCATED IN THE INDICATOR OR CONTROL DEVICE, OR ON THE CONTROL PANEL IMMEDIATELY ADJACENT THERE TO IN SUCH A MANNER AS TO POSITIVELY IDENTIFY THE INDICATOR OR CONTROL REQUIRING ACTION.**
  - A. LANDING GEAR
  - B. FIRE CONTROL
- 2.2.3.3 **CAUTION AND ADVISORY LIGHTS SHALL BE LOCATED IN CLOSE PROXIMITY TO THE INDICATOR OR CONTROL DEVICE WHERE ATTENTION TO THE INDICATOR OR CONTROL DEVICE IS THE PRIME FUNCTION OF THE SIGNAL.**
- 2.2.5 **SIGNAL FLAGS - WARNING AND ADVISORY:** SIGNAL FLAGS MAY BE USED WHERE SPECIFIC INDICATION IS ASSOCIATED WITH AN INSTRUMENT OR MECHANICAL DEVICE. WHERE THEY ARE SO USED THE FLAG SIGNAL WILL BE AN INTEGRAL PART OF THE INSTRUMENT OR DEVICE.
- 2.2.6 **AUDIBLE SIGNALS:** AUDIBLE SIGNALS ARE REQUIRED FOR ALL FIRE WARNING SYSTEMS AND OTHER CRITICAL SYSTEMS OR DEVICES WHERE VISUAL CHECKS OR WARNING MAY BE INSUFFICIENT TO GUARANTEE SAFETY. THEY MAY ALSO BE USED FOR OTHER FUNCTIONS NOT BEARING ON SAFETY BUT OF SUFFICIENT IMPORTANCE TO REQUIRE THEIR USE.

**TABLE E-1 (CONT)**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 450**

- 2.2.7 TACTUAL SIGNALS: TACTUAL SIGNALS MAY BE EMPLOYED TO ALERT PILOTS' ATTENTION WHERE VISUAL CHECK OR NORMAL SENSATIONS MAY BE INSUFFICIENT TO GUARANTEE SAFETY. THEY MAY ALSO BE USED FOR OTHER FUNCTIONS NOT BEARING ON SAFETY, BUT OF SUFFICIENT IMPORTANCE TO REQUIRE THEIR USE.
- 2.2.8 VOICE WARNING SYSTEMS: A SYSTEM THAT INDICATES TO THE FLIGHT CREW BY MEANS OF SPOKEN WORDS, A SAFETY FLIGHT MALFUNCTION OR ABNORMALITY.
- 2.2.8.1 WHEN A VOICE WARNING SYSTEM IS USED, IT MAY INCLUDE, BUT NOT BE LIMITED TO, ALL WARNINGS REQUIRING AN AUDIBLE SIGNAL AND SHALL INDICATE THE SPECIFIC ITEM CAUSING THE UNSAFE CONDITION.
- 2.2.8.2 THE WARNING MAY INCLUDE AN APPROPRIATE SIGNAL CORRESPONDING TO THE SPECIFIC ABNORMALITY AND SHALL OCCUR ALTERNATELY WITH THE VOICE SIGNAL.
- 2.2.8.3 AN ANNUNCIATOR PANEL SHALL BE INCLUDED IN THE SYSTEM TO INDICATE ABNORMAL CONDITIONS AS LONG AS THEY EXIST, IF A CANCELLABLE AURAL SIGNAL IS EMPLOYED.
- 2.2.8.4 A SILENCE SWITCH SHALL BE PROVIDED TO SILENCE THE AURAL SIGNALS ONLY AFTER THEY HAVE COMPLETED ONE CYCLE AND WILL RESET THE SYSTEM. NONCANCELLABLE TAKE-OFF AND LANDING WARNINGS CANNOT BE SILENCED.
- 2.2.8.5 THE VOICE WARNING SYSTEM WILL USE SEPARATE COCKPIT SPEAKERS AND THE COCKPIT INTERPHONE TO DISSEMINATE INFORMATION.
- 2.3.2 COLOR CODE-LIGHTS:
- 2.3.1 WARNING LIGHTS: WARNING LIGHTS WILL BE COLORED AVIATION RED, THE COLOR IS DEFINED IN SPECIFICATION AN-C-36-2, SECTION D-GENERAL REQUIREMENTS.
- 2.3 CAUTION LIGHTS: SHALL BE AMBER, AS DEFINED IN AN-C-36-2, SECTION D.
- 2.3.3 ADVISORY LIGHTS: MAY BE GREEN, BLUE, OR WHITE, AS DEFINED IN AN-C-36-2, SECTION D.
- 2.3.3.1 GREEN: USED TO INDICATE A SAFE CONFIGURATION OR CONDITION, WHEN USED IN CONJUNCTION WITH A WARNING LIGHT THE GREEN LIGHT WILL INDICATE THAT THE ACTION TAKEN HAS RESULTED IN COMPLETE SYSTEM OPERATION AND THE RESULTING CONFIGURATION IS SAFE.
- 2.3.3.2 BLUE: USED TO INDICATE THAT A SYSTEM IS ON AND OPERATING NORMALLY, OR THAT TRANSITORY ACTION IS TAKING PLACE (WITH THE EXCEPTION OF THE LANDING GEAR WARNING SYSTEM).
- 2.4.1.1 MASTER WARNING LIGHTS: THE INTENSITY OF THE MASTER WARNING, MASTER CAUTION AND WARNING LIGHTS WILL BE 275 MILLILAMBERTS FOR THE BRIGHT INTENSITY, AND 140 MILLILAMBERTS IF DIMMING IS USED.
- 2.4.1.4 CAUTION LIGHTS: THE INTENSITY OF CAUTION AND ADVISORY LIGHTS WILL BE 275 MILLILAMBERTS FOR THE BRIGHT INTENSITY AND CAPABLE OF DIMMING TO NOT LESS THAN 25 MILLILAMBERTS. IF CAUTION LIGHTS ARE LOCATED NEAR THE PRINCIPAL FLIGHT INSTRUMENTS THEY SHOULD DIM SO AS NOT TO INTERFERE WITH READING THE INSTRUMENTS DURING NIGHT FLIGHT WITH THE INSTRUMENT LIGHTS TURNED DOWN.
- 2.6.1 WARNING LIGHTS: WARNING, CAUTION AND ADVISORY LIGHTS WILL ILLUMINATE WHEN THE CONDITION TO BE WARNED REMAINS ILLUMINATED UNTIL ITS CAP IS PUSHED IN, OR UNTIL THE CONDITION IS CORRECTED, EITHER OF WHICH EXTINGUISHES THE MASTER WARNING AND RESETS IT FOR OTHER POSSIBLE FAILURES.
- 2.6.2 WARNING LIGHTS: WARNING CAUTION AND ADVISORY LIGHTS WILL ILLUMINATE WHEN THE CONDITION TO BE WARNED OR ADVISED OF OCCURS. THESE LIGHTS WILL REMAIN ON AS LONG AS THE CONDITION EXISTS OR UNTIL THE SYSTEM IS DEACTIVATED.

**TABLE E-1 (CONT)**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 450**

- 2.6.3 MASTER CAUTION LIGHT: WILL ILLUMINATE WHEN THE CONDITION TO BE ADVISED OF OCCURS. THE MASTER CAUTION SIGNAL REMAINS ILLUMINATED UNTIL ITS CAP IS PUSHED IN OR UNTIL THE CONDITION IS CORRECTED. EITHER OF WHICH EXTINGUISHES THE MASTER CAUTION SIGNAL AND RESETS IT FOR OTHER POSSIBLE ABNORMALITIES.
- 2.7.1 COLOR CODE: WHERE WARNING FLAGS ARE USED EXTERNALLY OR INDEPENDENTLY FROM INSTRUMENTATION, THEY SHOULD BE OF A BRIGHT YELLOW WITH BLACK DIAGONALS TO PROVIDE CONTRAST TO THE SURROUNDING AREA.  
  
WHERE WARNING FLAG INDICATORS ARE USED INTERNALLY IN INSTRUMENTS, THE COLOR SHOULD BE YELLOW, OR FLUORESCENT RED, WITH BLACK WORDING THEREON, IF REQUIRED.
- 2.7.2 WARNING FLAG OR INDICATORS INDEPENDENT FROM INSTRUMENT: FLAGS USED IN CONJUNCTION WITH MECHANICAL DEVICES INDEPENDENT OF INSTRUMENTATION WILL PROVIDE A CLEAR, UNMISTAKABLE WARNING THAT THE CONDITION TO BE WARNED OF HAS OCCURRED.
- 2.7.3 INSTRUMENT WARNING FLAGS OR INDICATORS: FLAGS USED IN CONJUNCTION WITH INSTRUMENTS WILL PROVIDE A CLEAR, UNMISTAKABLE WARNING THAT THE CONDITION TO BE WARNED OF HAS OCCURRED.
- 2.8 AUDIBLE SIGNAL-CODE:
  - 2.8.1 BELL: INDICATES "FIRE," FUNCTIONS AUTOMATICALLY AND SIMULTANEOUSLY WITH A FIRE WARNING LIGHT.
  - 2.8.2 HORN: INDICATES AN UNSAFE AIRCRAFT CONFIGURATION.  
SPECIFIC APPLICATIONS:
    - A. LANDING GEAR UNSAFE WITH THROTTLES RETARDED, OR WITH WING FLAPS IN THE LANDING CONFIGURATION, STEADY SOUND.
    - B. UNSAFE TAKEOFF CONFIGURATION UPON THROTTLE OPENING INTERMITTENT SOUND.
    - C. CABIN PRESSURE ABOVE 10,000 FEET INTERMITTENT SOUND.
  - 2.8.3 "CRICKET": INDICATES SPEED IN EXCESS OF  $V_{MO}$  -  $M_{MO}$ .
  - 2.8.4 GONG: USED FOR ALTITUDE ALERTING SYSTEM AND SPECIFIC WARNING ASSOCIATED WITH FLIGHT INFORMATION.
  - 2.8.5 CHIME: USED FOR ROUTINE OPERATIONAL INFORMATION.
  - 2.8.6 TONE: AN 800 CYCLE THREE NOTE CORD OF INCREASING AMPLITUDE MADE UP OF THE FOLLOWING FREQUENCIES: 512/640/768 Hz.
- 2.9 AUDIBLE SIGNAL SOUND LEVEL: THE LEVEL OF SOUND FOR ALL AURAL SIGNALS SHOULD BE THE MINIMUM LEVEL WHICH WILL BE CLEARLY DISTINGUISHABLE ABOVE THE NOISE LEVEL OF THE FLIGHT DECK FOR ALL CONDITIONS OF FLIGHT OPERATIONS OVER THE ENTIRE DESIGN ENVELOPE.
- 2.10 AUDIBLE SIGNALS TESTING: MEANS SHALL BE PROVIDED IN THE FLIGHT DECK AREA FOR TESTING AUDIBLE SIGNALS.
- 2.11 OPERATION OF AUDIBLE SIGNALS: THE AUDIBLE SIGNALS WILL SOUND WHEN THE CONDITION TO BE WARNED OF EXISTS.
  - 2.11.1 BELL:
    - A. THE WARNING BELL SHALL HAVE A PROVISION FOR CUT-OFF. IF CUTOFF IS AUTOMATIC, THE BELL WILL RING NOT LESS THAN ONE OR MORE THAN THREE SECONDS.

**TABLE E-1 (CONT)**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 450**

- B. THE CUT-OFF WILL NOT AFFECT CONTINUED OPERATION OF THE SIGNAL LIGHT.
  - C. THE CUT-OFF WILL AUTOMATICALLY RESET THE WARNING BELL FOR RECURRING FIRE IN THE SAME SYSTEM, OR FOR OCCURRENCE OF FIRE IN ANY OTHER SYSTEM, FOR EITHER MANUAL OR AUTOMATIC CUT-OFF.
- 2.11.2 HORN: THE WARNING HORN SHALL BE PROVIDED WITH A MANUAL CUT-OFF SWITCH. IT SHALL NOT BE POSSIBLE, HOWEVER, TO SILENCE THE HORN WITH THE CUT-OFF SWITCH:
- A. DURING TAKEOFF, EXCEPT BY CORRECTING THE UNSAFE TAKEOFF CONDITION.
  - B. IN FLIGHT WHEN THE WING FLAPS ARE IN THE LANDING CONFIGURATION.
- IF THE HORN SOUNDS IN FLIGHT AS A RESULT OF RETARDING THROTTLES AND THE HORN IS THEN SILENCED WITH THE CUT-OFF SWITCH, THE WARNING SYSTEM SHALL AUTOMATICALLY RESET FOR OPERATION UPON ADVANCEMENT OF THROTTLES.
- 2.11.3 "CRICKET": WILL BE FULLY AUTOMATIC IN OPERATION WITH NO CUT-OFF PROVIDED.
- 2.11.4 GONG: WILL BE FULLY AUTOMATIC IN OPERATION WITH NO CUT-OFF PROVIDED.
- 2.11.5 CHIME: WILL BE SOUNDED BY AN ACTUATING SWITCH OR BUTTON, AS REQUIRED.
- 2.12 TACTUAL SIGNALS PERCEPTIBILITY: THE INTENSITY OF TACTICAL SIGNALS SHALL BE SUCH AS TO ASSURE THEIR PERCEPTIBILITY UNDER ALL CONDITIONS.
- 2.13 TACTUAL SIGNALS TESTING: MEANS SHALL BE PROVIDED IN THE FLIGHT DECK AREA FOR TESTING TACTUAL SIGNALS.
- 2.14 OPERATION OF TACTUAL SIGNALS: THE TACTUAL SIGNALS WILL BE ACTIVATED WHEN THE CONDITION TO BE WARNED OF EXISTS, OR IMPENDS, AND WILL PERSIST UNTIL THE CONDITION IS CORRECTED. WHEN THE CONDITION IS CORRECTED THE TACTUAL SIGNAL WILL BE AUTOMATICALLY DEACTIVATED AND RESET FOR FUTURE RECURRENCE.

**TABLE E-2**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 571**

- 3.2.2** SELCALL SYSTEM MAY BE INSTALLED FOR PROVIDING VISUAL AND AURAL INDICATION OF A RADIO CALL INTENDED FOR THAT PARTICULAR AIRCRAFT.
- 3.2.2.1** VISUAL INDICATION SHALL BE PROVIDED FOR EACH RECEIVER FOR WHICH THE CALLING SYSTEM IS PROVIDED, BY AN ADVISORY LIGHT (OF A COLOR CONFORMING TO ARP 450). EACH LIGHT SHALL BE LOCATED AS CLOSE AS PRACTICAL TO THE RESPECTIVE RECEIVER'S FREQUENCY SELECTOR AND/OR VOLUME CONTROL.
- 5.1.1** THE FLIGHT DIRECTOR, AUTOPILOT, AND AUTOTHROTTLE SYSTEM MODE ANNUNCIATION DISPLAY SHALL PROVIDE A VISUAL INDICATION OF THE ARMING AND ENGAGEMENT OF ALL SELECTED MODES; AND, FOR SPECIFIED CASES, A VISUAL AND AURAL WARNING OF DISCONNECT CAUSED BY A SYSTEM FAULT OR BY PILOT ACTION.
- 5.1.3** THE MODE ANNUNCIATION DISPLAY SHALL BE LOCATED ON EACH PILOT'S FLIGHT INSTRUMENT PANEL WITHIN THE AREA OF THE "BASIC T" LAYOUT, PREFERABLY CENTRALLY ABOVE EACH ATTITUDE DIRECTOR INDICATOR (ADI).
- 5.5** MARKER EQUIPMENT INDICATION: A SET OF MARKER LIGHTS SHALL BE PROVIDED FOR THE CAPTAIN; IT IS CONSIDERED DESIRABLE TO ALSO PROVIDE A SET FOR THE CO-PILOT.
- 5.5.1** THE MARKER LIGHTS SHALL BE POSITIONED AT THE RIGHT END OF THE TOP ROW OF FLIGHT INSTRUMENTS AND SHALL BE FURTHER ARRANGED VERTICALLY AS FOLLOWS: UPPERMOST, WHITE-3000 CYCLE; MIDDLE, AMBER-1300 CYCLE; BOTTOM, BLUE-400 CYCLE. THE COLOR OF THE AMBER AND THE BLUE LIGHTS SHALL BE AS DEFINED IN AN-C-56-2, SECTION P.

**TABLE E-3**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 1068**

- 5.2 FAILURE WARNINGS: FAILURE WARNINGS FOR THE VARIOUS FUNCTIONS SHALL BE PROVIDED FOR THE PRIMARY FLIGHT PATH CONTROL INSTRUMENT SYSTEMS WHERE OTHER MEANS ARE NOT AVAILABLE FOR THE CREW TO IMMEDIATELY DETERMINE A FAILURE.
- 5.2.1 INDIVIDUAL FAILURE WARNING SHALL BE PROVIDED FOR EACH INSTRUMENT FUNCTION WHICH IS ESSENTIAL FOR CONTINUATION OF FLIGHT UNDER ANY OPERATION CONDITION.
- 5.2.2 FAILURE WARNINGS SHALL COVER MECHANICAL AND ELECTRICAL MALFUNCTIONS AS WELL AS POWER FAILURES. POWER FAILURE IS CONSIDERED AS ANY TYPE OF POWER DISCREPANCY WHICH WILL RESULT IN A MALFUNCTION OF THE DISPLAY.
- 5.2.3 PREFERRED METHOD OF FAILURE WARNING IS TO REMOVE THE AFFECTED DISPLAY FROM VIEW OR OTHERWISE PREVENT INADVERTENT USE OF THE FAILED DISPLAY.
- 5.2.4 WHEN A WARNING FLAG IS USED, IF PRACTICAL, IT SHOULD OBSCURE THE FUNCTION INDICATOR FOR WHICH THE WARNING IS PERTINENT.
- 5.3.1.2 THE AIRSPEED SYSTEMS SHALL INCORPORATE A WARNING FEATURE FOR SIGNIFICANT DISCREPANCIES IN EITHER OF THE SYSTEMS, INCLUDING THE INSTRUMENT READOUT.
- 5.3.2.6 THE VSI DISPLAY SHALL PROVIDE WARNING OF SIGNIFICANT DIFFERENCES IN SYSTEMS OUTPUT.
- 5.3.2.11 THE FLIGHT DIRECTOR COMPUTER FAILURE WARNING SHALL BE ACTIVATED BY FAILURE IN THE COMPUTER AND SHALL ALSO INDICATE FAILURES THAT HAVE OCCURRED IN ANY OF THE INPUTS TO THE COMPUTER THAT ARE BEING MONITORED.
- 5.3.3.1 A VISUAL ADVISORY SIGNAL SHALL BE PROVIDED TO ALERT THE CREW WHEN THE ASSIGNED ALTITUDE IS BEING APPROACHED OR VACATED.
- 5.3.3.3 THE RADIO ALTIMETERS SHALL INCORPORATE AN AURAL AND VISUAL WARNING OR ALERT SIGNAL AT DESIGNATED ALTITUDES ABOVE THE TERRAIN. THIS ALERT SIGNAL SHALL BE SEPARATE AND DISTINCT FROM THE SIGNAL IN PARAGRAPH 5.3.3.1. SEE ARP 450B FOR DESIGN CRITERIA OF THESE WARNING SIGNALS.
- 5.3.3.4 A WARNING SYSTEM SHALL WARN THE PILOT (VISUAL SIGNAL) WHEN A SIGNIFICANT DISCREPANCY EXISTS IN EITHER OF THE TWO BAROMETRIC DISPLAYS. THIS ALSO SHALL APPLY TO THE RADAR ALTIMETER DISPLAYS.
- 5.3.4.2 A WARNING SHALL BE PROVIDED TO INDICATE SIGNIFICANT DISCREPANCIES IN THE HB1 SYSTEMS.
- 5.3.5.2 WARNING, AUDIO AND VISUAL SIGNALS SHALL AUGMENT THE DISPLAY IN 5.3.5.1 ABOVE.
- 5.3.5.3 IT IS DESIRABLE THAT A RATE OF APPROACH TOWARD AN OPERATIONAL SITUATION OR LIMIT ALSO BE DISPLAYED AND WHERE NECESSARY SUITABLE WARNINGS BE PROVIDED.



**TABLE E-4**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 1161**

**5.5.2.2 BLACK BACKGROUNDS:**

**5.5.2.2.1 NONTRANSILLUMINATED SYSTEMS: THE BRIGHTNESS OF THE BLACK BACKGROUND SHALL HAVE A MAXIMUM VALUE OF 7% OF THE BRIGHTNESS OF NEARBY WHITE MARKINGS (WITHIN AN APPROXIMATE 0.25 IN. (6.35 MM) RADIUS), AND WHEREVER PRACTICAL NO LIGHT SHALL BE EMITTED FROM THE BLACK BACKGROUND.**

**TABLE I - DISPLAY COLORS**

<b>USE - TYPICAL</b>	<b>COLOR</b>	<b>COLOR DESCRIPTION*</b>
<b>DISPLAY MARKINGS:</b>		
PRIMARY	WHITE	37875
SECONDARY	BLUE	35177
EXTRANEIOUS	BLACK	27038
FLAG	BLACK	37038
<b>BACKGROUNDS:</b>		
DISPLAY	BLACK	37038
	DK. GRAY	36118
FLAG	RED	DAY-GLO FIRE ORANGE
	YELLOW	DAY-GLO SATURN YELLOW
<b>POINTERS, LUBBER LINES &amp; BUGS:</b>		
PRIMARY	WHITE	37875
SECONDARY	ORANGE	DAY-GLO ARC YELLOW
	RED	DAY-GLO FIRE ORANGE
NON-LIT AREAS	YELLOW	DAY-GLO SATURN YELLOW
	BLACK	37038
<b>LIMIT MARKS:</b>		
WARNING	RED	DAY-GLO FIRE ORANGE
CAUTION	YELLOW	DAY-GLO SATURN YELLOW
<b>RANGE BANDS:</b>		
	WHITE	37878
	YELLOW	DAY-GLO SATURN YELLOW
	GREEN	DAY-GLO SIGNAL GREEN
	RED	DAY-GLO FIRE ORANGE
<b>KNOBS:</b>		
HANDLE	LT. GRAY	36440
SKIRT	BLACK	37038
MARKINGS	WHITE	37875

\*1. COLOR NUMBERS NOTED IN THIS TABLE, INCLUDING THEIR FINISH, ARE PER FED-STD-595.

2. ALTHOUGH THE COLORS IDENTIFIED AS DAY-GLO SHALL MATCH IN COLOR THE RESPECTIVE COLORS OF THE DAY-GLO DAYLIGHT FLUORESCENT PAINTS MADE BY THE DAY-GLO COLOR DIVISION OF

**TABLE E-4 (CONT)**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 1161**

SWITZER BROS., INC., CLEVELAND, OHIO, THEY ARE NOT NECESSARILY REQUIRED TO HAVE THE FLUORESCENT CHARACTERISTICS OF THOSE PAINTS.

8. WARNING, CAUTION, AND ADVISORY SYSTEM LIGHTING

REFER TO THE LATEST ISSUE OF SAE ARP 450 FOR RECOMMENDATIONS ON WARNING, CAUTION, AND ADVISORY LIGHTING. AS AN OPTION, SECTIONS 8.1 THROUGH 8.10 CAN BE OMITTED.
- 8.1 PURPOSE: THE PURPOSE OF THIS SECTION IS TO PRESENT THE LIGHTING REQUIREMENTS FOR WARNING, CAUTION, AND ADVISORY SYSTEMS.
- 8.2 SCOPE: THIS SECTION SETS FORTH THE LIGHTING REQUIREMENTS FOR WARNING, CAUTION, AND ADVISORY SYSTEMS.
- 8.3 DEFINITIONS:
  - 8.3.1 MASTER WARNING: A SIGNAL INDICATING A CONDITION REQUIRING IMMEDIATE ACTION. THE SPECIFIC CONDITION IS SHOWN BY A SEPARATE INDICATION.
  - 8.3.2 INDEPENDENT WARNING: A SIGNAL INDICATING A CONDITION REQUIRING IMMEDIATE ACTION. THE SPECIFIC CONDITION IS DEFINED BY THE LOCATION OF THE SIGNAL OR THE LEGEND ASSOCIATED WITH THE SIGNAL.
  - 8.3.3 MASTER CAUTION: A SIGNAL INDICATING A CONDITION WHICH MAY REQUIRE ACTION. THE SPECIFIC CONDITION IS SHOWN BY A SEPARATE INDICATION.
  - 8.3.4 ADVISORY, SAFE: A SIGNAL INDICATING A SAFE CONDITION.
  - 8.3.5 ADVISORY, STATUS: A SIGNAL INDICATING A STATUS CONDITION ONLY, NOT NECESSARILY A SAFE CONDITION.
  - 8.3.6 DEPENDENT WARNING OR CAUTION: A SIGNAL INDICATING THE SPECIFIC CAUSE OF ACTIVATION OF THE MASTER WARNING OR CAUTION SIGNALS, RESPECTIVELY.
- 8.4 COLORS:
  - A. WARNING SIGNALS: AVIATION RED PER MIL-C-25050.
  - B. CAUTION SIGNALS: AVIATION YELLOW PER MIL-C-25050.
  - C. ADVISORY, SAFE: LIGHT GREEN PER DEVICE SPECIFICATION.
  - D. ADVISORY, STATUS: ANY COLOR INCLUDING WHITE EXCEPT THOSE ABOVE OR COLORS EASILY CONFUSED WITH THE ABOVE COLORS. A LIGHT (ICE) BLUE IS RECOMMENDED.
- 8.5 MASTER WARNING INDICATOR AND MASTER CAUTION INDICATOR: THE PURPOSE OF THESE INDICATORS IS TO INTRUDE UPON THE ATTENTION OF THE CREW MEMBERS UNDER ALL OPERATING CONDITIONS. THUS THE DESIGNER MUST CONSIDER PLACEMENT OF INDICATOR, AMBIENT LIGHTING, SHADING FROM DIRECT SUNLIGHT, SIZE OF LIT AREA, STEADY STATE VERSUS FLASHING AND BRIGHTNESS. MINIMUM BRIGHTNESS SHALL BE 150 FOOTLAMBERTS AT RATED VOLTAGE PROVIDED THE INDICATORS CAN BE PLACED OUT OF DIRECT SUNLIGHT. THE INDICATORS SHALL BE DIMMABLE TO 15 FOOTLAMBERTS. THE BRIGHT-DIM CONTROL SHALL RETURN TO FULL BRIGHT POSITION WHENEVER POWER IS REMOVED FROM THE CONTROL OR THE AMBIENT BRIGHTNESS REACHES A PREDETERMINED LEVEL. THE INDICATORS SHALL BE RESETTABLE SO THAT A SECOND SIGNAL SHALL REACTIVATE THE MASTER INDICATOR.
- 8.6 INDEPENDENT WARNING INDICATOR: IN GENERAL, THE INDEPENDENT WARNING INDICATOR SHALL MEET THE REQUIREMENTS OF 8.5 WITH THE FOLLOWING EXCEPTIONS: THE INDICATOR NEED NOT BE RESETTABLE; EITHER THE PLACEMENT OF THE INDICATOR OR AN ASSOCIATED LEGEND SHALL CLEARLY SHOW THE NATURE OF THE WARNING; THE DESIGNER SHALL CONSIDER ADDITIONAL DIMMING TO 5 FOOTLAMBERTS.

**TABLE E-4 (CONT)**  
**ALERTING SYSTEM REQUIREMENTS FOUND IN ARP 1161**

- 8.7**      **DEPENDENT WARNING AND CAUTION INDICATORS:** THESE INDICATORS SHALL BE ACTIVATED SIMULTANEOUSLY WITH THEIR RESPECTIVE MASTER INDICATOR AND SHALL SHOW THE SPECIFIC CAUSE OF THE MASTER INDICATOR ACTIVATION. IN GENERAL, THEIR BRIGHTNESS SHALL BE 150 FOOTLAMBERTS MINIMUM AT RATED VOLTAGE BUT THE REQUIRED BRIGHTNESS SHALL BE EVALUATED IN TERM OF OPERATING CONDITIONS AND LOWER BRIGHTNESS USED WHERE PRACTICABLE. THE INDICATORS SHALL BE DIMMABLE TO 15 FOOTLAMBERTS AND THE DESIGNER SHALL CONSIDER DIMMING TO VALUES APPROXIMATELY TWICE THE NOMINAL VALUES OF THE INTEGRALLY LIGHTED DISPLAYS.
- THE BRIGHT-DIM CONTROL SHALL RETURN TO FULL BRIGHT POSITION UNDER THE CONDITIONS DESCRIBED IN 8.5. THE INDICATORS SHALL NOT BE RESETTABLE WHILE THE ACTIVATING CONDITION EXISTS.
- 8.8**      **STATUS INDICATORS:** THE STATUS INDICATORS SHALL HAVE A BRIGHTNESS SUFFICIENT FOR LEGIBILITY UNDER ALL CONDITIONS OF FLIGHT OPERATION. THE DESIGNER SHALL CONSIDER LOCATION AND SHADING FROM SUNLIGHT TO ENHANCE READABILITY AT LOWER BRIGHTNESSES. THE INDICATORS SHALL BE DIMMABLE TO VALUES COMPARABLE TO THE INTEGRALLY LIT DISPLAYS OF SECTION 5.
- 8.9**      **LEGENDS:** IN GENERAL, WHERE INDICATORS HAVE LEGENDS, THE LEGEND SHOULD BE ON AN OPAQUE BACKGROUND. CONSIDERATION MAY BE GIVEN TO AN OPAQUE LEGEND ON A TRANSLUCENT BACKGROUND WHERE ADDITIONAL VISUAL STIMULUS IS CONSIDERED ESSENTIAL. LEGENDS SHOULD BE AS BRIEF AS POSSIBLE AND ONE LINE PRESENTATIONS ARE PREFERRED. IF ABBREVIATIONS ARE USED, THEIR MEANING SHOULD BE CLEAR TO AVOID MISINTERPRETATION.

**TABLE E-5**  
**SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS**  
**FOUND IN RTCA DOCUMENT NO. D0-161A**

- 1.6 WARNING AND ALERT INDICATIONS: DISTINCTIVE AURAL AND VISUAL WARNING MUST BE PROVIDED FOR MODES 1 THROUGH 4. A SEPARATE DISTINCTIVE AURAL ALERT MUST BE PROVIDED FOR MODE 5.
- 1.6.1 AURAL WARNING/ALERT: THE AURAL WARNING FOR MODES 1 THROUGH 4 SHALL CONSIST OF THE SOUND "WHOO-WHOO", FOLLOWED BY EITHER "PULL-UP" OR "TERRAIN" (OR OTHER ACCEPTABLE ANNUNCIATION) REPEATED UNTIL THE HAZARDOUS CONDITION NO LONGER EXISTS. THE WARNING MAY BE PROVIDED BY THE GPW EQUIPMENT ITSELF OR AN AUXILIARY WARNING UNIT WHICH IS ACTIVATED BY THE GPW EQUIPMENT.  
  
 THE AURAL ALERT FOR MODE 5 SHALL CONSIST OF THE ANNUNCIATION "GLIDE SLOPE" (OR OTHER ACCEPTABLE PHRASE) REPEATED UNTIL THE CONDITION RESPONSIBLE FOR THE ALERT NO LONGER EXISTS OR THE ALERT IS INHIBITED.
- 1.6.2 VISUAL WARNING CHARACTERISTICS (MODES 1 THROUGH 4): THE VISUAL WARNING PROVIDED FOR MODES 1 THROUGH 4 SHALL BE DISTINCTIVE UNDER ALL NORMAL LIGHTING CONDITIONS AND COMMENSURATE WITH OTHER COCKPIT WARNINGS.
- 1.6.3 EMERGENCY/PLANNED ABNORMAL DEACTIVATION: MEANS TO DEACTIVATE THE WARNING INDICATIONS (MODES 1 THROUGH 4) MAY BE PROVIDED, AND MEANS TO DEACTIVATE THE ALERT INDICATION (MODE 5) MUST BE PROVIDED FOR FLIGHT CREW USE IN PLANNED ABNORMAL OR EMERGENCY CONDITIONS.
- 2.3 CHARACTERISTICS OF WARNING INDICATIONS (MODES 1 THROUGH 4)
- 2.3.1 AURAL WARNING CHARACTERISTICS: THE AURAL WARNING FOR MODES 1 THROUGH 4 CONSISTS OF THE SOUND "WHOO-WHOO," FOLLOWED BY EITHER "PULL-UP" OR "TERRAIN" (OR OTHER ACCEPTABLE ANNUNCIATION) REPEATED UNTIL THE HAZARDOUS CONDITION NO LONGER EXISTS. IT IS NOT NECESSARY FOR ANY WARNING CYCLE ("WHOO-WHOO" PLUS VOICE ANNUNCIATION) TO BE COMPLETED FOLLOWING THE TERMINATION OF A HAZARDOUS CONDITION. "WHOO-WHOO" IS DESCRIBED AS A TONE SWEEP FROM 400 Hz  $\pm$  10% TO 800 Hz  $\pm$  10% AT A PERIOD OF 0.3 SECONDS  $\pm$  20% AND WITH INCREASING AMPLITUDE OF 9 dB  $\pm$  3 dB. THE COMPLETE CYCLE OF TWO TONE SWEEPS PLUS VOICE ANNUNCIATION SHOULD TAKE 1.4 SECONDS  $\pm$  20%, WITH THE CYCLE REPEATED IMMEDIATELY. THE GAIN MAY BE AUTOMATICALLY REDUCED AFTER THREE COMPLETE WARNING CYCLES TO A LOWER, BUT DISCERNABLE, LEVEL.
- 2.3.1.1 SPEAKER OUTPUT LEVEL: THE VOICE WARNING SIGNAL SHALL HAVE AN OUTPUT LEVEL OF AT LEAST 2W RMS.
- 2.3.1.2 HEADSET OUTPUT LEVEL: IF PROVIDED, THE HEADSET VOICE WARNING SIGNAL SHALL HAVE AN OUTPUT LEVEL OF AT LEAST 50 mW.
- 2.3.2 VISUAL WARNING: THE VISUAL WARNING FOR MODES 1 THROUGH 4 SHALL BE RED AND INCLUDE, IN DISTINCTIVE LETTERS, THE LETTERS GPWS (OR OTHER ACCEPTABLE LEGEND).
- 2.4 DEACTIVATION CONTROL: THE CONTROL FOR DEACTIVATION OF THE WARNING INDICATIONS UNDER PLANNED ABNORMAL OR EMERGENCY CONDITIONS SHALL BE A CIRCUIT BREAKER. ALTERNATIVELY A SWITCH WHICH IS PROTECTED FROM INADVERTENT CREW OPERATION MAY BE USED. SUCH A SWITCH SHALL PROVIDE OBVIOUS INDICATION IT HAS BEEN OPERATED.
- 2.6 GLIDE SLOPE DEVIATION ALTERING (MODE 5)
- 2.6.1 ENVELOPE OF CONDITIONS FOR ALERTING: AN ALERT SHALL BE PROVIDED WHEN THE COMBINATION OF DEVIATION BELOW AN ILS GLIDE SLOPE AND THE HEIGHT ABOVE TERRAIN IS WITHIN THE ENVELOPE FOR MODE 5 PRESCRIBED IN APPENDIX A.
- 2.6.2 DEACTIVATION: IT SHALL BE POSSIBLE FOR THE FLIGHT CREW TO DEACTIVATE MODE 5. THE CONTROL PROVIDED FOR THIS PURPOSE SHALL BE SEPARATE FROM ANY CONTROL PROVIDED TO DEACTI-

**TABLE E-5 (CONT)**  
**SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS**  
**FOUND IN RTCA DOCUMENT NO. D0-161A**

VATE MODES 1 THROUGH 4. THE MODE 1 THROUGH 4 DEACTIVATION CONTROL, HOWEVER, MAY ALSO DEACTIVATE MODE 5.

- 2.6.3 REACTIVATION: IF MODE 5 IS DEACTIVATED BY THE PILOT, IT SHALL BE AUTOMATICALLY REACTIVATED FOR THE NEXT APPROACH.
- 2.6.4 ARMING/DISARMING: MODE 5 SHALL BE ARMED WHEN THE LANDING GEAR IS SELECTED TO THE LANDING POSITION AND DISARMED EITHER WHEN THE FLAPS ARE RETRACTED FROM THE LANDING POSITION OR THE LANDING GEAR IS SELECTED TO THE NON-LANDING POSITION.
- 2.6.5 GLIDE SLOPE MODE ALERT: THE GLIDE SLOPE DEVIATION ALERT SHALL CONSIST OF THE AURAL ANNUNCIATION "GLIDE SLOPE" (OR OTHER ACCEPTABLE ANNUNCIATION) REPEATED UNTIL THE CONDITION RESPONSIBLE FOR THE ALERT NO LONGER EXISTS OR THE ALERT IS INHIBITED. AN AURAL WARNING RELATED TO GPWS MODES 1 THROUGH 4 SHALL TAKE PRECEDENCE OVER THIS ALERT.

THE EQUIPMENT MAY PROVIDE A CONSTANT ALERT REPETITION RATE AND AUDIO OUTPUT LEVEL, OR ONE OR BOTH OF THESE QUANTITIES MAY INCREASE AS THE BELOW GLIDE SLOPE DEVIATION INCREASES AND/OR THE TERRAIN CLEARANCE DECREASES. IN THE FORMER CASE THE ALERT SHALL BE REPEATED AT LEAST ONCE EVERY THREE SECONDS. THE AUDIO OUTPUT POWER LEVELS MAY TAKE ON ANY VALUE BETWEEN 0 AND 6dB BELOW THOSE VALUES SPECIFIED FOR THE MODES 1 THROUGH 4 AURAL WARNING IN PARAGRAPHS 2.3.1.1 AND 2.3.1.2.

IF THE REPETITION RATE/AUDIO OUTPUT LEVEL IS/ARE VARIED WITH TERRAIN CLEARANCE/GLIDE SLOPE DEVIATION, THE ALERT SHOULD BE REPEATED ONCE EVERY SEVEN SECONDS (NOMINAL) AT 1000 FEET TERRAIN CLEARANCE AND THE AUDIO LEVELS BE DISCERNABLE TO THE PILOT. AS THE TERRAIN CLEARANCE DECREASES AND/OR THE GLIDE SLOPE DEVIATION INCREASES, THE ALERT RATE SHOULD INCREASE TO A MAXIMUM OF ONCE EVERY 0.7 SECONDS AND THE AUDIO OUTPUT POWER LEVELS TO THE MAXIMUM OF THOSE VALUES SPECIFIED FOR THE MODES 1 THROUGH 4 AURAL WARNING IN PARAGRAPHS 2.3.1.1 AND 2.3.1.2.

**TABLE E-6**  
**SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS IN MIL-STD-1472**

- 3.1 LIGHT SIGNALS:**
- 3.1.1 NON-LEGEND TYPE:** A NON-LEGEND LIGHT SIGNAL ASSEMBLY IS ONE WHICH HAS NO MARKINGS ON ITS LIGHT TRANSMITTING SURFACE.
- 3.1.2 LEGEND TYPE:** A LEGEND LIGHT SIGNAL ASSEMBLY IS ONE WHICH HAS THE LEGEND ON ITS LIGHT TRANSMITTING SURFACE.
- 3.1.3 WARNING LIGHT:** A WARNING LIGHT IS A SIGNAL ASSEMBLY WHICH INDICATES THE EXISTENCE OF A HAZARDOUS CONDITION REQUIRING IMMEDIATE CORRECTIVE ACTION.
- 3.1.1.5 MASTER WARNING LIGHT RESET:** THE MASTER WARNING LIGHT SHALL HAVE A PUSH-TO-RESET CAPABILITY WHICH DEENERGIZES THE MASTER WARNING LIGHT WHILE THE APPLICABLE LEGEND WARNING LIGHT REMAINS "ON." THE MASTER WARNING LIGHT AND ANY APPLICABLE WARNING LIGHT(S) SHALL BE ENERGIZED SIMULTANEOUSLY.
  - A. THE AIRCRAFT POWER SETTING IS LESS THAN THAT REQUIRED TO MAINTAIN LEVEL FLIGHT IN THE POWER APPROACH CONFIGURATION.**
  - B. THE FLAPS OR OTHER HIGH-LIFT DEVICES ARE NOT FULLY RETRACTED.**
  - C. THE WHEELS ARE NOT DOWN AND LOCKED.**
- 3.1.4 MASTER WARNING LIGHT:** A MASTER WARNING LIGHT IS A SIGNAL ASSEMBLY WHICH INDICATES THAT AT LEAST ONE OR MORE WARNING LIGHTS HAVE BEEN ENERGIZED.
- 3.1.5 CAUTION LIGHT:** A CAUTION LIGHT IS A SIGNAL ASSEMBLY WHICH INDICATES THE EXISTENCE OF AN IMPENDING DANGEROUS CONDITION REQUIRING ATTENTION BUT NOT NECESSARILY IMMEDIATE ACTION.
- 3.1.6 MASTER CAUTION LIGHT:** A MASTER CAUTION LIGHT IS A SIGNAL ASSEMBLY WHICH INDICATES THAT ONE OR MORE CAUTION LIGHTS HAVE BEEN ACTUATED.
- 3.1.7 ADVISORY LIGHT:** AN ADVISORY LIGHT IS A SIGNAL ASSEMBLY TO INDICATE SAFE OR NORMAL CONFIGURATION, CONDITION OF PERFORMANCE, OPERATION OF ESSENTIAL EQUIPMENT, OR TO ATTRACT ATTENTION AND IMPART INFORMATION FOR ROUTINE ACTION PURPOSES.
- 3.2 AUDITORY WARNING SIGNALS:** AUDITORY WARNING SIGNALS ARE AUDIBLE SIGNALS INDICATING THE EXISTENCE OF A HAZARDOUS CONDITION(S) REQUIRING IMMEDIATE CORRECTIVE ACTION.
- 5.1.1 WARNING LIGHTS:** LEGEND WARNING LIGHTS SHALL BE USED IN ALL AIRCREW STATIONS. A MASTER WARNING LIGHT, WHEN REQUIRED, SHALL BE ENERGIZED SIMULTANEOUSLY WITH ANY APPLICABLE WARNING LIGHT.
- 5.1.1.1 COLOR:** THE COLOR OF THE WARNING LIGHTS SHALL BE AVIATION RED.
- 5.1.2 CAUTION LIGHTS:** LEGEND TYPE MASTER CAUTION AND LEGEND TYPE CAUTION LIGHTS SHALL BE USED IN ALL AIRCREW STATIONS. THE MASTER CAUTION LIGHT AND ANY APPLICABLE LEGEND CAUTION LIGHT SHALL BE ENERGIZED SIMULTANEOUSLY.
- 5.1.2.1 COLOR:** THE COLOR OF THE CAUTION LIGHTS SHALL BE AVIATION YELLOW.
- 5.1.2.6 MASTER CAUTION LIGHT RESET:** THE MASTER CAUTION LIGHT SHALL HAVE A PUSH-TO-RESET CAPABILITY WHICH DEENERGIZES THE MASTER CAUTION LIGHT WHILE THE APPLICABLE LEGEND CAUTION LIGHT REMAINS "ON."
- 5.1.3 ADVISORY LIGHTS:** EVERY ATTEMPT SHOULD BE MADE TO MINIMIZE THE USE OF ADVISORY LIGHTS IN THE COCKPIT AREA, PRIMARILY TO AVOID UNNECESSARY DISTRACTION OF THE PILOTS AND TO MINI-

**TABLE E-6 (CONT)**  
**SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS IN MIL-STD-411**

MIZE THOSE FACTORS WHICH DETERIORATE NIGHT VISION CAPABILITY OF THE CREW. THEY SHALL NOT BE USED WHERE OTHER METHODS, SUCH AS SWITCH LABELING, MECHANICAL VISUAL SIGNALS, ETC., MAY BE EMPLOYED. ADVISORY LIGHTS MAY BE EITHER OF THE LEGEND OR NON-LEGEND TYPE, IN THE EVENT THAT A LEGEND LIGHT IS NOT EMPLOYED, A READILY IDENTIFIABLE LABEL SHALL BE PROVIDED ADJACENT TO THE LIGHT, PREFERABLY ABOVE.

- 5.1.3.1 COLOR: THE COLOR OF ADVISORY LIGHTS IN THE FLIGHT COMPARTMENT SHALL BE AVIATION GREEN. GREEN, BLUE, OR WHITE COLORS MAY BE USED IN OTHER CREW STATIONS.
- 5.2.1 MASTER WARNING SIGNALS: A NON-VERBAL AUDIO MASTER WARNING SIGNAL SHALL PRODUCE AN OUTPUT WITH THE FOLLOWING FREQUENCY AND INTERRUPTION RATES:
  - A. FUNDAMENTAL AUDIO OUTPUT FREQUENCY SHALL SWEEP FROM 700 Hz TO 1,700 Hz IN 0.85 SECOND.
  - B. INTERRUPTION INTERVAL 0.12 SECOND.
  - C. THE CYCLE SHALL BE REPEATED UNTIL THE SIGNAL GENERATOR IS DEENERGIZED.
- 5.2.3 WHEELS-UP-SIGNAL: WHEN A NON-VERBAL AUDIO WHEELS-UP SIGNAL IS USED, IT SHALL HAVE THE FOLLOWING TONE:
 

FREQUENCY  $250 \pm 50$  Hz, FUNDAMENTAL TONE INTERRUPTED AT  $5.0 \pm 1.0$  Hz WITH A  $50 \pm 10$  PERCENT ON-OFF CYCLE.
- 5.2.4 AUDIO ANGLE OF ATTACK/AIRSPED/STALL WARNING SIGNAL: WHEN A NON-VERBAL AUDIO SIGNAL IS USED FOR PRESENTING ANGLE OF ATTACK/AIRSPED/STALL WARNING INFORMATION, REFERENCED TO A SELECTED ANGLE OF ATTACK/AIRSPED/STALL SPEED, IT SHALL BE AS NOTED IN TABLE IV. THE DISCRETE POSITION AT WHICH THE CHOPPED SIGNAL COMMENCES ON EITHER SIDE OF THE "CORRECT" SIGNAL WILL BE READILY ADJUSTABLE.
- 5.2.5 VERBAL AUDITORY WARNING SIGNALS: VERBAL WARNING SIGNALS SHALL BE AUDIBLE SIGNALS IN VERBAL FORM INDICATING THE EXISTENCE OF A HAZARDOUS OR IMMINENT CATASTROPHIC CONDITION REQUIRING IMMEDIATE ACTION AND SHALL ONLY BE USED TO COMPLEMENT RED WARNING OR OTHER CRITICAL VISUAL SIGNALS. THE VERBAL WARNING SIGNALS SHALL BE PRESENTED AT LEVELS WHICH WILL INSURE OPERATOR RECEPTION UNDER NOISE CONDITIONS IN THE SPECIFIC AIRCRAFT, THERE SHALL BE PROVISION FOR OVERRIDING AND RESETTNG THE SIGNALS. THE SIGNAL, WHEN ACTIVATED, SHALL ALWAYS START AT THE BEGINNING OF THE MESSAGE AND SHALL CONTINUE TO BE PRESENTED UNTIL EITHER:
  - A. THE CAUSATIVE CONDITION IS CORRECTED.
  - B. A WARNING OF HIGHER PRIORITY IS PRESENTED.
  - C. THE SIGNAL IS SILENCED BY MANUAL ACTUATION OF THE OVERRIDE SWITCH.

THE STRUCTURE FOR VERBAL WARNINGS SHALL BE:

  - A. GENERAL HEADING--I.E., THE SYSTEM OR SERVICE INVOLVED
  - B. SPECIFIC SUBSYSTEM OR LOCATION
  - C. NATURE OF EMERGENCY

**TABLE E-6 (CONT)**  
**SYNOPSIS OF ALTERING SYSTEM REQUIREMENTS IN MIL-STD-411**

**TABLE IV**  
**AUDIO ANGLE OF ATTACK/AIRPEED/STALL**  
**WARNING SIGNAL**

ANGLE OF ATTACK	AIRPEED	TONE SIGNAL
LOW	FAST	1,600 TONE INTERRUPTED AT A RATE OF 1 TO 10 Hz, THE RATE INCREASING LINEARLY WITH DECREASING ANGLE OF ATTACK/INCREASING AIRSPEED.
SAFE LOW	SAFE FAST	900 Hz STEADY TONE, PLUS 1,600 Hz TONE INTERRUPTED AT A RATE OF ZERO TO 1 Hz, THE RATE INCREASING LINEARLY WITH DECREASING ANGLE OF ATTACK/INCREASING AIRSPEED.
CORRECT	CORRECT	900 Hz STEADY TONE.
SAFE HIGH	SAFE LOW	900 Hz STEADY TONE, PLUS 400 Hz TONE INTERRUPTED AT A RATE OF ZERO TO 1 Hz, THE RATE INCREASING LINEARLY WITH INCREASING ANGLE OF ATTACK/DECREASING AIRSPEED.
HIGH	SLOW	400 Hz TONE INTERRUPTED AT A RATE OF 1 Hz TO 10 Hz, THE RATE INCREASING LINEARLY WITH INCREASING ANGLE OF ATTACK/DECREASING AIRSPEED (STALL WARNING).

- 5.4.1.2 WARNING LIGHTS: WARNING LIGHTS SHALL BE INSTALLED WITHIN THE PILOT'S 30-DEGREE CONE OF VISION. WHEN SPACE IS LIMITED OR THE REQUIRED NUMBER OF WARNING LIGHTS IS EXCESSIVE, WARNING LIGHTS MAY BE GROUPED OUTSIDE OF THE PILOT'S 30-DEGREE CONE OF VISION. IN THESE CASES, A MASTER WARNING LIGHT SHALL BE INSTALLED IN THE PILOT'S 30-DEGREE CONE OF VISION, AND IN ADDITION, A MASTER AUDITORY WARNING SIGNAL MAY BE USED.
- 5.4.1.3.2 SIDE-BY-SIDE PILOT COCKPITS: CAUTION LIGHTS SHALL BE GROUPED AT THE LOWER PORTION OF THE CENTER INSTRUMENT PANEL BELOW THE INSTRUMENTS OR ON THE CENTER PEDESTAL IMMEDIATELY AFT OF THE POWER QUADRANT. THE LIGHTS SHALL BE VISIBLE TO BOTH PILOTS.
- 5.4.4.5 SIDE-BY-SIDE PILOT COCKPITS: A MASTER CAUTION LIGHT SHALL BE INSTALLED ON THE UPPER PORTION OF THE INSTRUMENT PANEL WITHIN BOTH PILOTS' 30-DEGREE CONE OF VISION. IF THE ABOVE CRITERIA CANNOT BE MET WITH ONE LIGHT ASSEMBLY, THEN TWO MASTER CAUTION LIGHTS SHALL BE INSTALLED.
- 5.4.4.4.2 ADVISORY LIGHTS: ADVISORY LIGHTS SHALL BE GROUPED CATEGORICALLY OR FUNCTIONALLY WHERE PRACTICAL, OR ASSOCIATED WITH A SPECIFIC UNIT OR COMPONENT, AND SHALL BE SO LOCATED THAT THEY CAN BE OBSERVED FROM THE OPERATOR'S NORMAL POSITION, EXCEPT WHERE SPECIFICALLY AUTHORIZED, ADVISORY LIGHTS SHALL NOT BE LOCATED ON THE MAIN INSTRUMENT PANEL OR SUBPANEL IN THE COCKPIT.



**TABLE E-7**  
**SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS IN MIL-STD-1472**

- 5.2.2.1.1** **USE:** TRANSILLUMINATED INDICATORS SHOULD BE USED TO DISPLAY QUALITATIVE INFORMATION TO THE OPERATOR (PRIMARILY, INFORMATION THAT REQUIRES EITHER AN IMMEDIATE REACTION ON THE PART OF THE OPERATOR, OR THAT HIS ATTENTION BE CALLED TO AN IMPORTANT SYSTEM STATUS). SUCH INDICATORS MAY ALSO BE USED OCCASSIONALLY FOR MAINTENANCE AND ADJUSTMENT FUNCTIONS.
- 5.2.2.1.5** **GROUPING:** MASTER CAUTION, MASTER WARNING, MASTER ADVISORY AND SUMMATION LIGHTS USED TO INDICATE THE CONDITION OF AN ENTIRE SUBSYSTEM SHALL BE SET APART FROM THE LIGHTS WHICH SHOW THE STATUS OF THE SUBSYSTEM COMPONENTS, EXCEPT AS REQUIRED UNDER PARAGRAPH 5.2.2.1.8.
- 5.2.2.1.6** **LOCATION:** WHEN A TRANSILLUMINATED INDICATOR IS ASSOCIATED WITH A CONTROL, THE INDICATOR LIGHT SHALL BE SO LOCATED AS TO BE IMMEDIATELY AND UNAMBIGUOUSLY ASSOCIATED WITH THE CONTROL AND VISIBLE TO THE OPERATOR DURING CONTROL OPERATION.
- 5.2.2.1.7** **LOCATION, CRITICAL FUNCTIONS:** FOR CRITICAL FUNCTIONS, INDICATORS SHALL BE LOCATED WITHIN 15° OF THE OPERATOR'S NORMAL LINE OF SIGHT (SEE FIGURE 2). WARNING LIGHTS SHALL BE AN INTEGRAL PART OF, OR LOCATED ADJACENT TO, THE LEVER, SWITCH, OR OTHER CONTROL DEVICE BY WHICH THE OPERATOR IS TO TAKE ACTION.
- 5.2.2.1.18** **COLOR CODING:** WITH THE EXCEPTION OF AIRCREW STATION SIGNALS WHICH SHALL CONFORM TO MIL-STD-411, AND TRAINING EQUIPMENT WHICH SHALL CONFORM TO MIL-T-23991, TRANSILLUMINATED LIGHT EMITTING DIODE (LED) AND INCANDESCENT DISPLAYS SHALL CONFORM TO THE FOLLOWING COLOR CODING SCHEME, IN ACCORDANCE WITH TYPE I-AVIATION COLORS OF MIL-C-23050.
- A.** RED SHALL BE USED TO ALERT AN OPERATOR THAT THE SYSTEM OR ANY PORTION OF THE SYSTEM IS INOPERATIVE, OR THAT A SUCCESSFUL MISSION IS NOT POSSIBLE UNTIL APPROPRIATE CORRECTIVE OR OVERRIDE ACTION IS TAKEN. EXAMPLES OF INDICATORS WHICH SHOULD BE CODED RED ARE THOSE WHICH DISPLAY SUCH INFORMATION AS "NO-GO", "ERROR", "FAILURE", "MALFUNCTION", ETC.
  - B.** FLASHING RED SHALL BE USED ONLY TO DENOTE EMERGENCY CONDITIONS WHICH REQUIRE OPERATOR ACTION TO BE TAKEN WITHOUT UNDUE DELAY, TO AVERT IMPENDING PERSONNEL INJURY, EQUIPMENT DAMAGE, OR BOTH.
  - C.** YELLOW SHALL BE USED TO ADVISE AN OPERATOR THAT A CONDITION EXISTS WHICH IS MARGINAL, YELLOW SHALL ALSO BE USED TO ALERT THE OPERATOR TO SITUATIONS WHERE CAUTION, RECHECK, OR UNEXPECTED DELAY IS NECESSARY.
  - D.** GREEN SHALL BE USED TO INDICATE THAT THE MONITORED EQUIPMENT IS IN TOLERANCE OR A CONDITION IS SATISFACTORY AND THAT IT IS ALL RIGHT TO PROCEED (E.G., "GO-AHEAD", "INTOLERANCE", "READY", "FUNCTION ACTIVATED", "POWER ON", ETC.).
  - E.** WHITE SHALL BE USED TO INDICATE SYSTEM CONDITIONS THAT DO NOT HAVE "RIGHT" OR "WRONG" IMPLICATIONS, SUCH AS ALTERNATIVE FUNCTIONS (E.G., MISSILE NO. 1 SELECTED FOR LAUNCH, ETC.) OR TRANSITORY CONDITIONS (E.G., ACTION OR TEST IN PROGRESS, FUNCTION AVAILABLE), PROVIDED SUCH INDICATION DOES NOT IMPLY SUCCESS OR FAILURE OF OPERATIONS.
  - F.** BLUE MAY BE USED FOR AN ADVISORY LIGHT, BUT PREFERENTIAL USE OF BLUE SHOULD BE AVOIDED.
- 5.2.2.1.19** **FLASHING LIGHTS:** THE USE OF FLASHING LIGHTS SHALL BE MINIMIZED. FLASHING LIGHTS MAY BE USED ONLY WHEN IT IS NECESSARY TO CALL THE OPERATOR'S ATTENTION TO SOME CONDITION REQUIRING ACTION. THE FLASH RATE SHALL BE WITHIN 3 TO 5 FLASHES PER SECOND WITH APPROXIMATELY EQUAL AMOUNTS OF ON AND OFF TIME. THE INDICATOR SHALL BE SO DESIGNED THAT, IF IT IS ENERGIZED AND THE FLASHER DEVICE FAILS, THE LIGHT WILL ILLUMINATE AND BURN STEADILY (SEE 5.3.2.4).

**TABLE E-7 (CONT)**  
**SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS IN MIL-STD-1472**

- 5.2.6.5**     **FLAGS:**
- 5.2.6.5.1**   **APPLICATION:** FLAGS SHOULD BE USED TO DISPLAY QUALITATIVE, NON-EMERGENCY CONDITIONS.
- 5.2.6.5.3**   **MALFUNCTION INDICATION:** WHEN FLAGS ARE USED TO INDICATE THE MALFUNCTION OF A VISUAL DISPLAY, THE MALFUNCTION POSITION OF THE FLAG SHALL AT LEAST PARTIALLY OBSCURE THE OPERATOR'S VIEW OF THE MALFUNCTIONING DISPLAY AND SHALL BE READILY APPARENT TO THE OPERATOR UNDER ALL EXPECTED LEVELS OF ILLUMINATION.
- 5.2.6.5.6**   **TEST PROVISION:** A CONVENIENT MEANS SHALL BE PROVIDED FOR TESTING THE OPERATION OF FLAGS.
- 5.3.4.3.6**   **PROHIBITED TYPES OF SIGNALS:** THE FOLLOWING TYPES OF SIGNALS SHALL NOT BE USED AS WARNING DEVICES WHERE POSSIBLE CONFUSION MIGHT EXIST BECAUSE OF THE OPERATIONAL ENVIRONMENT:
- A.   MODULATED OR INTERRUPTED TONES THAT RESEMBLE NAVIGATION SIGNALS OR CODED RADIO TRANSMISSIONS.
  - B.   STEADY SIGNALS THAT RESEMBLE HISSES, STATIC, OR SPORADIC RADIO SIGNALS.
  - C.   TRAINS OF IMPULSES THAT RESEMBLE ELECTRICAL INTERFERENCE WHETHER REGULARLY OR IRREGULARLY SPACED IN TIME.
  - D.   SIMPLE WARBLER WHICH MAY BE CONFUSED WITH THE TYPE MADE BY TWO CARRIERS WHEN ONE IS BEING SHIFTED IN FREQUENCY (BEAT-FREQUENCY-OSCILLATOR EFFECT).
  - E.   SCRAMBLED SPEECH EFFECTS THAT MAY BE CONFUSED WITH CROSS MODULATION SIGNALS FROM ADJACENT CHANNELS.
  - F.   SIGNALS THAT RESEMBLE RANDOM NOISE, PERIODIC PULSES, STEADY OR FREQUENCY MODULATED SIMPLE TONES, OR ANY OTHER SIGNALS GENERATED BY STANDARD COUNTERMEASURE DEVICES (E.G., "BAGPIPES").
  - G.   SIGNALS SIMILAR TO RANDOM NOISE GENERATED BY AIR CONDITIONING OR ANY OTHER EQUIPMENT.
  - H.   SIGNALS THAT RESEMBLE SOUNDS LIKELY TO OCCUR ACCIDENTLY UNDER OPERATIONAL CONDITIONS.
- 5.3.5**     **VERBAL WARNING SIGNALS:**
- 5.3.5.1**   **NATURE OF SIGNALS:** VERBAL WARNING SIGNALS SHALL CONSIST OF:
- A.   AN INITIAL ALERTING SIGNAL (NONSPEECH) TO ATTRACT ATTENTION AND TO DESIGNATE THE GENERAL PROBLEM.
  - B.   A BRIEF STANDARDIZED SPEECH SIGNAL (VERBAL MESSAGE) WHICH IDENTIFIES THE SPECIFIC CONDITION AND SUGGESTS APPROPRIATE ACTION.
- 5.3.5.6.1**   **CRITICAL WARNING SIGNALS:** CRITICAL WARNING SIGNALS SHALL BE REPEATED WITH NOT MORE THAN A 3-SECOND PAUSE BETWEEN MESSAGES UNTIL THE CONDITION IS CORRECTED OR OVERRIDDEN BY THE CREW.
- 5.3.6.2**   **AUTOMATIC RESET:** WHETHER AUDIO WARNING SIGNALS ARE DESIGNED TO BE TERMINATED AUTOMATICALLY, BY MANUAL CONTROL, OR BOTH, AN AUTOMATIC RESET FUNCTION SHALL BE PROVIDED. THE AUTOMATIC RESET FUNCTION SHALL BE CONTROLLED BY THE SENSING MECHANISM WHICH SHALL RECYCLE THE SIGNAL SYSTEM TO A SPECIFIED CONDITION AS A FUNCTION OF TIME OR THE STATE OF THE SIGNALING SYSTEM.

**TABLE E-8**  
**SYNOPSIS OF ALERTING SYSTEM REQUIREMENTS IN MIL-C-81774**

- 3.5.7** PANEL MARKINGS SHALL BE WHITE EXCEPT WHEN ILLUMINATED OR WHEN THEY DENOTE EMERGENCY ACTION CONTROLS.
- 3.6.2.1** LEGEND ILLUMINATED PUSHBUTTONS SHOULD HAVE A STROKE WIDTH BORDER.
- 3.6.3** LIGHTED DISPLAYS (INCLUDING ALERTING DEVICES) SHALL HAVE A MINIMUM CONTRAST RATIO OF 3 IN A 10,000 FOOT-CANDLE AMBIENT.
- 3.9.1 D.** REDUNDANCY IN THE DISPLAY OF INFORMATION TO A SINGLE OPERATOR SHOULD BE AVOIDED UNLESS REDUNDANCY IS REQUIRED TO ACHIEVE A SPECIFIED RELIABILITY.
- E.** INFORMATION NECESSARY FOR PERFORMING DIFFERENT ACTIVITIES, SUCH AS OPERATION AND TROUBLE-SHOOTING, SHOULD NOT BE COMBINED IN A SINGLE DISPLAY UNLESS THE ACTIVITIES ARE COMPARABLE FUNCTIONS AND REQUIRE THE SAME INFORMATION.
- 3.9.2.1.3** AN ADVISORY LIGHT IS AN ILLUMINATED SIGNAL ASSEMBLY WHICH INDICATES SAFE OR NORMAL CONFIGURATION, CONDITION OF PERFORMANCE, OR OPERATION OF ESSENTIAL EQUIPMENT, OR WHICH ATTRACTS ATTENTION AND IMPARTS INFORMATION FOR ROUTINE ACTION PURPOSES. THE USE OF ADVISORY LIGHTS SHOULD BE MINIMIZED. THEY SHOULD NOT BE USED WHERE OTHER METHODS, SUCH AS SWITCH LABELING, MECHANICAL VISUAL SIGNALS, ETC., MAY BE EMPLOYED.
- 3.11.9** AN ARRAY OF PUSHBUTTONS SERVING AS AN INTEGRATED CONTROL SHOULD BE ARRANGED SUCH THAT, IN A LATERAL ARRAY, LEFT-TO-RIGHT PROGRESSION IS IN THE ORDER OF INCREASING PRIORITY OR SEQUENCE, AND IN A LONGITUDINAL ARRAY, THE FORWARD PROGRESSION INDICATES ORDER OF INCREASING PRIORITY OR SEQUENCE.

## **APPENDIX F**

### **BACKGROUND DATA FOR FORMULATION OF ALERT PRIORITIZATION RATIONALE**

#### **F.0 INTRODUCTION**

This appendix presents a historical series of working papers and dissertations used to develop the proposed method of prioritizing alerting functions. The papers are presented in chronological sequence. Each major section in this appendix denotes a historical break point in the commercial aviation industry's development of alerting system standards.

**49TH MEETING OF SAE S-7 COMMITTEE  
APRIL 1976**

**STANDARDS AND CRITERIA FOR DESIGN OF  
AN INTEGRATED WARNING SYSTEM**

The lists of warnings that are presented here are oriented more to importance of the warning rather than being broken into the categories of configuration, flight profile, and systems as had been suggested. The reason for this was that it seemed that a system or installation designed to accomplish our objectives would at least address the Level I and part of Level II, as appropriate, depending on cost and complexity. Level III type of items are lower priority and would reduce the checklist significantly but quite likely would be of higher cost and complexity.

In considering an operational installation, one concept might be to use a multiline readout (see Figure 1) with the computer logic as noted under the visual and audio alert columns. By tying the audio alert to takeoff thrust application, or to being airborne, or to descent to a height near the ground most of the nuisance audio alerts can be eliminated. This would mean that the system would be in the "ground mode" or "before takeoff mode" all the time when on the ground — the readout would show items not set for takeoff but the audio would be silent until the throttles are advanced. Similarly, in flight below 2500' the "landing mode" would be energized and the readout would show items not in proper configuration for landing but no audio would sound until descent through 1000' had occurred with the aircraft still not in configuration. This type of logic must be thoroughly thought out and evaluated so please, let us have your ideas!!

If there were more than five or six discrepancies, the remaining ones would appear on the readout device or devices as soon as the previous discrepancies were cleared. Also, there would have to be a provision to cancel the audio in the event of an engine shutdown or loss of a particular system and for other reasons. It may not be desirable to cancel the visual; let it serve as a reminder. Possibly we might need more than five or six lines for discrepancies after we look at all possibilities. The readout device would provide the crew a self-check or confidence check during the pre-start and pre-takeoff phase since its monitoring of the various items would be apparent to the crew.

Level I items would remain as currently implemented, i.e., specially dedicated systems. Level II A consists mostly of the present-day warnings that excite an audio signal. An integrated warning system would offer the most benefit by including the items in this group. Items in Level II B and II C are highly desirable but the associated costs would require individual consideration for each item.

**AIRCRAFT OPERATIONS AND SYSTEMS MONITOR**

It is recommended that an integrated monitor and warning system be implemented wherein a visual alert or annunciation provision and a single audio alert signal be employed to bring to the flight crew's attention any faults or airplane configuration incompatibilities. The aircraft monitor and warning system should not in any way create confusion on the part of the flight crew, should alert them to a fault or discrepancy in a timely fashion and should result in reduced crew workload.

The aircraft faults and discrepancies can be broken into three levels of importance or urgency:

	Tactile	Visual	Audio
<b>Level I (Immediate Action)</b>	<u>Alert</u>	<u>Alert</u>	<u>Alert</u>
1. Engine Fire	None	Cont.	Cont.
2. Stall or Sudden Loss of Lift	Cont.	None	Cont.-Airborne
3. Inadvertent Ground Proximity	None	Cont.	Voice/Cont.
<b>Level II (Flight Safety-Action Required)</b>			
<b>A.)</b>	<u>Alert</u>		<u>Alert</u>
1. Cabin Altitude-Too Hl (rate & height)	Cont.		Cont.
2. Spoilers-Extended	On Flaps Ext.		* Tg&1000' R.A.
3. T.E. & L.E. Flaps-Impropr. Set	On Ground		Tg&1000' R.A.
4. Airspeed-VMO, MMO Exceedance	Cont.		Cont.
5. Altitude Diversion-(Flight Profile)	200' After Cptr.		300' Aft. Cptr.
6. Landing Gear-UP	Landing Flaps		1000' R.A.
7. Stabilizer-Impropr. Set	On Ground		Tg
8. Other A/C Config-Unsafe	Ldg.Flaps&/or On Grnd.		Tg&1000' R.A.
9. Flap Placard-Exceeded	Cont.		Cont.
10. Landing Gear Placard-Exceeded	Cont.		Cont.
11. Engine Thrust Setting-Over Limits	Cont.		Cont.
12. Wheel Well Fire	Cont.		Cont.
13. APU Fire	Cont.		Cont.
14. Radio Altimeter	Cont.		Cont.
<b>Level II</b>			
<b>B.)</b>	<u>Alert</u>		<u>Alert (Optional)</u>
1. Hydraulic Press. & Quant-Low	Cont.		Cont. After Tg
2. Engine Oil Press. & Quant-Low	Cont.		Cont. After Tg
3. Essential Elect. Pwr-Fail	Cont.		Cont. After Tg
*4. Auto-Pilot & Autothrottle-Disconnect	*Cont.		*Cont.
5. Instr. Comparator Sys-Alert	Cont.		Cont.
6. Gyro & Compass Flags-Visible	Cont.		Cont.
7. Cabin & Exterior Doors-Not Closed	Cont.		Cont. After Tg
8. Pitot Heat-Off	Cont.		Cont. After Tg
9. Window Heat-Off	Cont.		Cont. After Tg
10. Anti-Skid-Off	Cont.		Cont. After Tg
11. Engine Fuel Switch-Off	Cont.		Cont. After Tg
12. CADC-Failed	Cont.		Cont.
13. Nav System-Failed	Cont.		Cont.
<b>Level II</b>			
<b>C.)</b>	<u>Alert</u>		<u>Alert</u>
1. Emergency Flap Switch-Not Off	On Ground		None
2. Rudder & Spoiler Switch-Not On	On Ground		None
3. INS-Not Nuv	On Ground		None

4. Yaw Damper-Not On	On Ground	None
5. Rudder & Aileron Trim-Not Zero	On Ground	None
6. Battery-Not On	On Ground	None
7. Compass Cont-Not Mag	Cont.	None
8. Instr. Transfer Switch-Not Norm	On Ground	None

**Level III** (All other items that have less effect on basic safety of flight, i.e., additional checklist items)

	<u>Visual</u> <u>Alert</u>	<u>Audio</u> <u>Alert</u>
1. Emerg. Exit Lights-Not Armed	Cont.	None
2. Pneumatic Brake Press-Below 1200 psi	Cont.	None
3. Static Source-Not Norm	Cont.	None
4. Start Levers-Not as Req'd	Cont.	None
5. Gear Pins-Not Pulled	Cont.	None
6. Air Cond-Not as Req'd	Cont.	None
7. Galley Power-Not as Req'd	Cont.	None
8. Beacon-Not On	Cont.	None
9. Parking Brakes-Not as Req'd	Cont.	None
10. Eng. Fuel Heat-Not Off	Cont.	None
11. No Smoking & Seat Belts-Not as Req'd.	Cont.	None
12. Anti-Ice, Engine-Not Off	Cont.	None
13. Smoke Detector System-Not On	Cont.	None
14. Ground Start Switches-Not Off	Cont.	None
15. Elect. System-Not Norm (No Lights)	Cont.	None

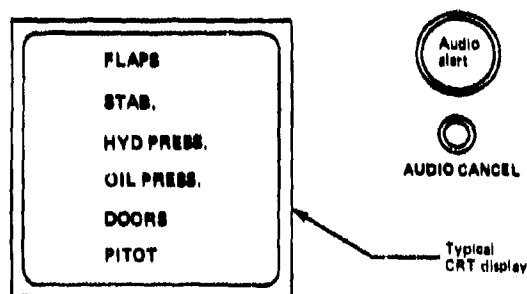
\*II B.)4. Two pushes on Disconnect button cancels warning

\*Tg = Application of T.O. Thrust on Ground

\*1000' R.A. = 1000 Ft. Radio Altitude on Approach

Cont. = Continuous Monitor

A/B = Airborne



*Figure 1. Sample Readout During Engine Start*

CAUTION WARNING SYSTEM						
PRIORITY	REQUIREMENTS		STIMULI		TYPE OF FAULTS	REMARKS
	CREW RECOGNITION TIME	CREW ACTION TIME	AURAL/TACTILE	LIGHT/ANNUNCIATORS		
I  W A R N I N G	IMMEDIATE RECOGNITION REQUIRED	IMMEDIATE ACTION REQUIRED	DISTINCTIVE AURAL/TACTILE	ANNUNCIATOR AND RED MASTER LIGHT	SUDDEN LIFT LOSS GRO PROX ENGINE FIRE	SHOULD CONSIDER AUTOMATIC ACTION AND/OR LOWER PRIORITY WARNING BEFORE CONDITION IS CRITICAL. (ENGINE OVERHEAT, ETC.)
	IMMEDIATE RECOGNITION REQUIRED	ACTION REQUIRED SOON	AURAL (HORN)	ANNUNCIATOR AND RED LIGHT	CABIN ALT UNSAFE CONF AIRSPEED WARN ALTITUDE APU/WW FIRE ENGINE RED LINE	
III  C A U T I O N	RECOGNITION REQUIRED	ACTION REQUIRED WITHIN 10 MINUTES	NO AURAL	CAUTION ANNUNCIATOR AND MASTER AMBER LIGHT	PRIMARY INSTR/SENSOR FAILURE MAJOR SYSTEM FAILURE ITEMS REQUIRING ALTERNATE CREW PROCEDURES	INHIBIT MASTER FOR T/O ROLL TO FEET AND FINAL APPROACH EXCEPT FOR RECALL ON BEFORE TO AND LANDING
	RECOGNITION DESIRED	NO ACTION REQUIRED	NO AURAL	ANNUNCIATOR	SYSTEM STATUS CHANGES THAT HAVE NO EFFECT ON FLIGHT, BUT WHICH ADDITIONAL FAILURE WOULD ALTER FLIGHT OR REQUIRE ACTION	
V  A D V I S O R Y	RECOGNITION ONLY WHEN CHECKING SYSTEM	NO ACTION	NO AURAL	NO MASTER LIGHT OR ANNUNCIATION	MINOR SYSTEM FAILURE OR CHANGES THAT ARE NOT IN I, II, III, OR IV	



**VIEWPOINTS ON DESIGN OF WARNING/CAUTION SYSTEMS****1. GENERAL**

In today's aircraft aural and visual warnings/cautions have proliferated to an extent that makes it difficult for the pilot to distinguish between them. It is, therefore, desirable to centralize the warnings and more carefully scrutinize the need for individual warnings and, where needed, make them more explicit.

In order to minimize nuisance warnings, the warning systems should be provided with logic that inhibits the warning in case of a technical failure in the system or the stage of flight is such that a warning is irrelevant or distracting, for example a fire warning at lift-off or at low altitude during an approach.

**2. AURAL WARNINGS**

Warnings that require immediate recognition and actions shall be aural, each using a specific sound supplemented by a visual display and preferably also by voice.

If the number of aural warnings, including tactile warnings, exceeds 7 they must be supplemented by voice.

Other warnings and cautions should be announced by a common sound supplemented by voice and/or a visual display.

Aural warnings shall be loud enough to be heard under all flight conditions but low enough not to interfere with cockpit communication.

**3. VISUAL WARNINGS**

Warnings and cautions should be presented on an alphanumeric display in front of each pilot.

The display should be capable of displaying at least 3 warnings simultaneously.

The light intensity of the alphanumeric display should be manually adjustable with automatic compensation for changes in cockpit light level.

Individual lights should be connected to a central dimming circuit.

Failures in redundant systems should not be announced as warnings or cautions when no pilot action is required. Such failures should be shown on a system status display.

Whenever possible, controls that must be actuated in case of a warning should be illuminated or indicated by some other means.

It should be possible to clear the display by a push-button, but the warning should be stored in a memory as long as it persists and be redisplayed in case of a new warning.

It should be possible to recall warnings from the memory with a recall button. A test button for confidence check should be provided.

Since it is doubtful that all individual warning and caution lights can be eliminated the remaining ones should have dual light bulbs separated by a light barrier and if peripherally located they should be flashing.

Instrument failure warnings should be designed in such a way that the affected display is removed or, if this is not possible, obscured by a warning flag. Even if the display is removed a warning flag shall be displayed.

#### 4. SHORT TERM ACTION ITEMS

1. Make up a proposal for a centralized visual/aural integrated warning system.
2. Enumerate warnings and cautions that need to be fed to the Central Warning system.
3. Define inhibit logics that are necessary to minimize nuisance warnings.

#### 5. STUDY ITEMS

Simulator studies should be made to determine if there is any benefit to be gained from the following refinements.

1. Display of the checklist valid, for the warning condition, on a malfunction display.
2. Automatic execution of this checklist after pilot's initiation.
3. Schematic display of failed system with indication of failed and usable portion of system.

**F.2 CRITERIA FOR ALERTING FUNCTION CATEGORIES DEVELOPED BY THE BOEING COMPANY EARLY IN THIS STUDY**

*Table F-1 Criteria for Caution and Warning Categories*

CATEGORY		CATEGORY CRITERIA	
CATEGORY*		CRITERIA RECOMMENDED BY BOEING ENGINEERS	CRITERIA RECOMMENDED BY BOEING PILOTS
1		Hazardous flight conditions or aircraft systems conditions which require immediate corrective or compensatory action by the crew	Non-hazardous flight conditions or aircraft systems conditions which require immediate corrective or compensatory action by the crew
2		Hazardous flight conditions or aircraft systems conditions which require (1) if the aircraft is stable, immediate corrective or compensatory crew action, or (2) if the aircraft is not stable, corrective or compensatory crew action as soon as the aircraft can be stabilized	Potentially hazardous flight conditions or aircraft systems conditions which require immediate corrective or compensatory crew action if the flight is to proceed further
3		Hazardous flight conditions or aircraft systems conditions which require near term corrective or compensatory crew action. "Near term" indicates that action should be taken during the next low workload period	System failures that require operation with degraded capability could affect the planned flight
4		Potentially hazardous flight conditions or aircraft systems conditions which require crew awareness of the condition and no near term corrective or compensatory crew action. However, these conditions may require modification of the planned or usual aircraft operating conditions during the remainder of the flight so as to avoid getting into a hazardous situation	Checking items that should be accomplished for safe operation. This category is for "crew failure to accomplish" items
5		Non-hazardous flight conditions or transitory aircraft systems conditions which require crew awareness, but no crew action, near term or long term	Non-hazardous flight conditions or transitory aircraft systems conditions which require crew awareness, but no crew action, near term or long term

\*These categories represent broad groups of alerts having approximately equal levels of importance/priority. Category 1 alerts have highest priority and Category 5 alerts have lowest priority. Higher priority alerts may interrupt lower priority alerts at any time.

The alerts falling within each category will vary from one aircraft to another. The alert priorities within each category (if required) and the application of alert inhibits during certain phases of flight will also vary from one aircraft to another. Specific criteria for defining these priorities and inhibit philosophies need to be developed.

### F.3 APPLICATION OF PROBABILITY AND SEVERITY OF EFFECTS CRITERIA DEVELOPED IN BCAR PAPER NO. 670 TO ALERTING SYSTEMS

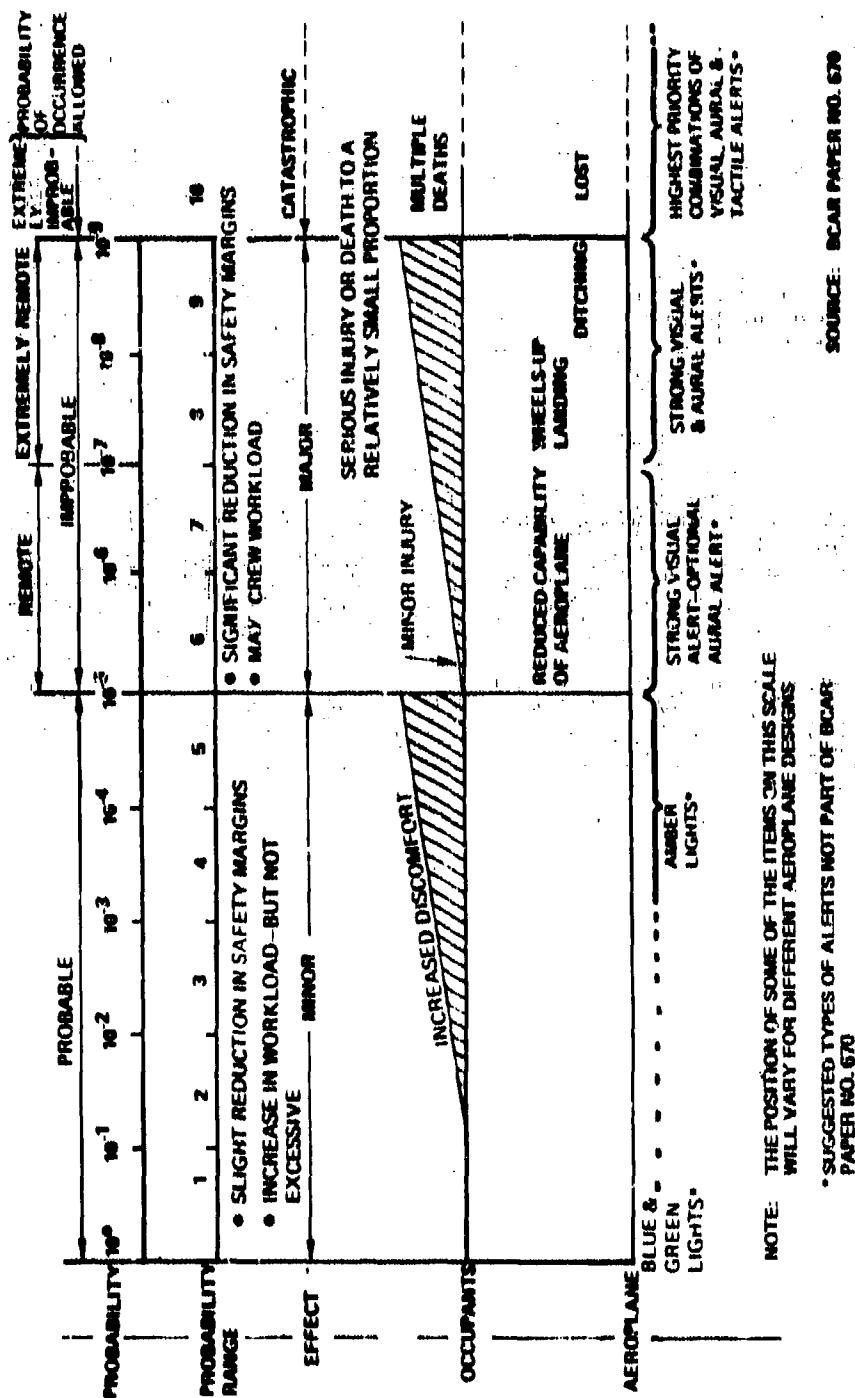


Figure F-1 Relationship Between Probability and Severity of Effects

$$\begin{aligned}
 & P \left\{ \left( \text{FAILURE} \right) + \left( \text{FAILURE RESULTING IN INJURIES IF NOT CORRECTED OR COMPENSATED FOR WITHIN } \underline{\hspace{1cm}} \text{ SECONDS} \right) + \left( \text{FAILURE RESULTING IN INJURIES DURING A LATER PART OF THE FLIGHT IF NOT COMPENSATED FOR OR CORRECTED} \right) + \left( \text{CREW NOT DETECTING ALERT WITHIN } \underline{\hspace{1cm}} \text{ SECONDS} \right) \right\} \\
 & + \left\{ \left( \text{CREW NOT RESPONDING TO SITUATION CORRECTLY WITHIN } \underline{\hspace{1cm}} \text{ SECONDS} \right) + \left( \text{CREW NOT RECALLING EARLIER FAILURES THAT HAVE A MAJOR EFFECT ON CURRENT OPERATIONS} \right) + \left( \text{MAJOR EVENT CAUSING INJURY} \right) \right\} < P
 \end{aligned}$$

Figure F-2 Potential Method for Prioritizing Alerting Functions

**F.4 ALTERNATE SET OF ALERTING FUNCTION CATEGORY CRITERIA DEVELOPED AT  
THE BOEING COMPANY**

*Table F-2 Caution and Warning System Concept*

<b>AIRPLANE CONDITION CRITERIA</b>	<b>CATE- GORY</b>	<b>CREW RECOGNITION/ RESPONSE TIME</b>	<b>EXAMPLES OF CONDITIONS OR EVENTS</b>
<b>INTRINSICALLY HAZARDOUS</b>	<b>1</b>	<b>MINIMUM CREW REACTION TIME, WITHOUT HESITATION OR LOSS OF TIME. "IMMEDIATE"</b>	<ul style="list-style-type: none"> <li>● STALL WARN</li> <li>● GROUND PROX</li> <li>● EMER CABIN ALT RATE/LEVEL</li> </ul>
<b>EXTRINSICALLY HAZARDOUS. THOSE WHICH IN THEMSELVES ARE NOT HAZARDOUS, BUT ARE KNOWN THROUGH EXPERIENCE TO BE CONDITIONALLY HAZARDOUS.</b>	<b>2</b>	<b>DEFERRED POSITIVE (PREDETERMINED COURSE OF ACTION)</b>	<ul style="list-style-type: none"> <li>● EXCEED <math>V_{MO}/M_{MO}</math></li> <li>● ENGINE FIRE</li> <li>● ENGINE OIL PRESS./OIL LOW</li> </ul>
	<b>3</b>	<b>DEFERRED CONDITIONAL (COURSE OF ACTION CONTINGENT UPON OTHER CONDITIONS)</b>	<ul style="list-style-type: none"> <li>● PROBE HEAT INOP</li> <li>● WINDOW HEAT FAIL</li> <li>● HYD PRESS/QT</li> <li>● GEN DISCONNECT</li> <li>● A/T DISC</li> </ul>
<b>HAZARDOUS UNDER NO CONDITIONS. SUPER- NUMERARY BY NATURE.</b>	<b>4</b>	<b>ACTION REQUIRED AT NO TIME</b>	<ul style="list-style-type: none"> <li>● FLIGHT RECORDER INOP</li> <li>● SELCAL</li> <li>● STEW CALL</li> </ul>

\*DEVELOPED BY J. OHLSON, THE BOEING COMPANY, 1976

**WORKING PAPER  
AN INTEGRATED AIRCRAFT WARNING SYSTEM  
FOR  
SAE COMMITTEE S-7**

**I THE DELIVERY SYSTEM AND ITS PHILOSOPHY**

- A. As a first step toward evolving a delivery system, it was necessary to enumerate the faults of present systems.
1. Present warning systems have "grown like Topsy" with more added, it seems, each time there is an accident. The result has been a proliferation of discrete aural warnings to the extent that there can be confusion as to the meaning of a specific aural warning. The crew must first determine which of several potential problems is triggering the aural warning being heard before taking action.
  2. The level of urgency in terms of flight conditions is not presently annunciated. The crew must evaluate this level to determine the requirements for immediacy of action and division of attention between the problem and conduct of the flight.
  3. Too many warnings occur during normal operational conditions. Any warning that is heard repeatedly when no action is really required will be psychologically "blocked out", including any recollection of inhibiting the warning. Even if the warning "gets through", the crew must still determine if it is a real or a nuisance warning before taking action. There are several reasons for the occurrence of warnings in normal conditions:
    - a. Faulty design logic
    - b. Poorly considered regulatory requirements
    - c. Lack of reliability resulting in nuisance warnings
  4. Noise levels of existing audio warnings may be so high and so annoying as to degrade the human response capability. This is often due to a regulatory requirement for a minimum decibel limit to "get attention", which, in turn, is related to several of the problems listed above. As a spinoff of this specific problem, an inhibit capability is often required to remove the raucous audio before intelligent action can be taken.
- B. In seeking solutions to existing faults in warning system philosophy, the working group was able to construct a model of a desirable system.
1. To replace the multitude of aural warnings, a single unique tone should be utilized for all problems requiring aural alert. This tone should be complemented by a visual display, and oral annunciation, declaring the nature and location of the problem.

2. The level of urgency should be annunciated by repeating the tone one, two or three times, or by otherwise modifying the tone while retaining its unique nature. Urgency level should also be annunciated by color coding of the message on the visual display.
3. Design logic, very high reliability, and regulatory changes must be created to eliminate the problem of unnecessary and nuisance warnings.
4. The tone, being unique and meaningful can be soft and non-irritating. It is believed that its very uniqueness and dedication will allow it to "cut through" ambient noise because crews will be attuned to its sound, much as the sound of an engine room telegraph will raise a ship captain from the deepest sleep. Having heard one tone the crew will be immediately attentive to see if a second will occur and, that happening, will be doubly attentive for a third. We do not wish to see a button required to inhibit the tone and voice warning. Since they are compelling enough to get attention and specific enough to spell out the problem, they should be non-repetitive. Any requirements for recall can be provided for by the visual display.
5. Several cases came up where our design philosophy was at odds with present regulation. In order to achieve the optimum logic, the group elected to proceed as though there were no regulatory constraints. This may soon have to be resolved.
6. It was argued that some may wish to retain existing discrete audio warnings on the grounds that they have withstood the test of time. (The fire bell is an example.) Though wishing to discourage such a prospect, we decided to include an option for a limited number of discrete aural warnings with the admonition that these should be kept to a minimum and used only for the highest urgency level.

## II LEVELS OF URGENCY (See Table One)

- A. After lengthy discussion it was concluded that four, rather than three levels of urgency would be needed. This concept made it difficult to accommodate the levels with the desired tone repetitions of one, two and three times. An acceptable solution was reached by creating a fourth level, zero, to be the lowest level of urgency. Thus, level zero would have no aural tone, no visual display and no voice annunciation. Warning would be provided by lights much as they exist today.
  1. Level III would be described as *emergency*, *urgent* or *serious*. Action required would be *immediate*. Warning would be provided by three aural tones, a visual display and voice annunciation of the problem.
  2. Level II would be described as *caution* or *abnormal*. Action required would be *prompt*. Warning would be provided by two aural tones and a visual display, with voice annunciation recommended.
  3. Level I would be described as *irregular*. Action would be required but may be deferred. Warning would be provided by one aural tone and a visual display, with voice annunciation optional.



4. Level Zero would be described as *advisory*. Later action may or may not be required. Warning would be provided by visual means, such as a light or flag.
- B. The various warnings are categorized by urgency level in tables two through five. Some points of discussion follow:
1. Decision height, selcal, and cabin call alerts present a special problem. By nature they are of the lowest priority level, but placing these in level Zero would deprive them of aural alerting. If they are placed in level I, then the aural tone would be applied, but we would be violating our philosophy of having no warnings for normal conditions. To create a discrete aural sound for these conditions is one solution, but would add an extra audio. This needs further discussion.
  2. The ground proximity/high sink warning has been included in the three higher levels to account for different flight conditions. This was not unanimous and the logic for this problem needs further exploration.
  3. We have assigned low urgency level (level I) to a CADC failure, although such a failure has far reaching significance. The rationale for this is that several other failure warnings would be displayed simultaneously in case of a CADC failure. Some of these, such as autopilot disconnect, have a higher urgency level.
  4. The warnings for landing gear door open and gear not properly stowed we assigned to level Zero, so that lights presently used would be applicable to these problems.
  5. On the engine over limit warning for level II, we believe the annunciation should be simply "engine number 2 over limit". The crew then could refer to their engine instruments to determine which parameter is over limit.
  6. On the instrument comparator warning for level I, we believe we should have the soft aural tone and the visual display would annunciate the parameter that is out of order, such as compass, altitude indicator, etc.

### III INHIBIT AND OTHER LOGIC

- A. In some cases we were able to apply logic to the conditions. In many other cases, the considerations were so complex that time did not permit our completing this task. Where we assigned logic it appears in the tables under "remarks". Much work remains to be done in this area.
- B. One theory that was agreed to is that, during critical flight phases, such as takeoff and landing, selective inhibits should be applied as the aircraft approaches the most critical point until at that point perhaps no warning would be given. Then the inhibits may be selectively removed as the aircraft progresses toward a less critical condition so that all warnings would be active at some later point.

### IV PRIORITIES

Time permitted assigning priorities only to level III. (Illustrated by A, B, and C on table two.) A great deal of work remains to be done on this task.

## **V OTHER UNRESOLVED ISSUES**

- A. Consideration must be given to the effects of radio altimeter failure, both on dispatch and warning capability. Much logic will probably be based on radio altitude.**
- B. Autopilot malfunctions and their effects need further expansion.**
- C. There is a need to find the optimum aural tone for crew alert. Tape samples should be constructed.**
- D. Some philosophy must be added on dimming, cancellation and recall of the visual display. (Sture Bostrom has done some work on this.)**
- E. The precise means of color-coding the visual display must be developed.**
- F. This working paper must be hardened and worked into format of ARP 1068.**

# TABLE ONE

## General System Concepts

1. Aural attention getter
  - prefer unique tone for all problems
  - should define level of urgency by 2 or 3 repetitions or by slightly modifying tone
  - should not be annoyingly loud
  - should not require silencing (NON repetitive)
2. Discrete sounds may be used on a selective basis
  - should be limited in number
  - suggest for most urgent level only
3. Checklist Requirements not incorporated (?)
4. Should have priority system which includes phase of flight
5. The visual display should employ color-coding to indicate the urgency level of the warning being annunciation.
6. Consideration should be given to inhibiting certain warnings during critical phases of flight, such as takeoff, low approach, etc.
7. In some cases the priority system should inhibit secondary mode warnings.

## Levels of Urgency

III	Emergency	Immediate Action Required		
	Urgent Serious			
	(1) Aural	AG*	(2) Visual	(3) Voice Annunciation Recommended
II	Caution	Prompt Action Required		
	Abnormal			
	(1) Aural	AG	(2) Visual	(3) Voice Annunciation Optional
I	Irregular	Action Required		
	(1) Aural	AG	(2) Visual	
0	Advisory	May Require Action Later		
	(1) Visual	AG#		

\*Very limited number of discrete aural warnings is optional  
 #such as light or flag  
 AG = attention getter

## TABLE TWO

### LEVEL III

#### Typical Problem

#### Remarks

(A) III Stall ———

Inhibited on ground

(B) III Ground Prox/hi sink

—

(C) III A/P - inadvertent disconnect

(non red syst. & below 500 R/A)

# TABLE THREE

## LEVEL II

Typical Problem	Remarks
Engine fire	Phase of flight
Engine Failure (catastrophic)	Phase of flight
Degraded takeoff performance	Possible future
Overrotation (rate or angle)	Takeoff
Excessive wind shear	Possible future below 1000' RA, TO or APP
High Cabin alt.	10,000 ft.
A/P - Inadvertent disconnect	Non-redundant syst. above 500' RA
A/T - Inadvertent disconnect	
Takeoff Warning (spoilers, hi lift dev., brakes stab.)	Early speed warning (60 KGS)
Ground prox/high sink	Logic to be determined
Dev. from Aas. Alt. Mmo, Vmo, Tmo	Regulatory considerations
Cargo compt. Fire/smoke	only where cockpit action is possible
A.P.U. fire Galley fire/smoke Wheel well fire	only where cockpit action is possible
Engine over limit	Appropriate parameters for eng. first limit
Hydraulic press./quant.	single syst. remaining
Flt. inst. power failure	Where manual switching req.
Gear unsafe for landing	Logic to be determined.

## TABLE FOUR

### LEVEL I

Excessive rate of change of cabin press.

Instrument warning

Prognosis of wind shear potential

Lavatory fire/smoke

Hydraulic press./quan. Multiple systems remaining

Engine oil press./quan.

Flight inst. power failure where syst. restoration is automatic

Inst. comparator alert

CADC failure

Inadvertent stabilizer in motion

Ground prox./high sink

## **TABLE FIVE**

### **LEVEL 0**

**A/P in reversion (i.e., Turb Mode, etc.)**

**Navigation system fail (recommend to sys. designers that if a guidance input has failed that the appropriate command bar, etc., be removed from view ARP 1068)**

**Antiskid off/fail (if this item were on Level I could eliminate from the approach checklist)**

**Radio altimeter failure**

**Gyro or compass flag visible**

**Exterior doors not closed**

**Yaw damper fail**

**Instrument transfer switch not normal**

**Landing gear door open**

**Gear not properly stowed**

**Autopilot stabilizer out of trim**

**WORKING PAPER**  
**AN INTEGRATED AIRCRAFT WARNING SYSTEM**  
**SAE - COMMITTEE S-7**

Comments on the above Working Paper

**I THE DELIVERY SYSTEM AND ITS PHILOSOPHY**

**A.**

**Item 2:** I am of the opinion that using the MASTER WARNING/MASTER CAUTION system, as installed in most of the present day aircraft, the level of urgency is annunciated - maybe not optimal but at least usable. As a consequence, two different kind of checklists exist, namely the EMERGENCY CHECKLIST and the MAL-FUNCTION OR ABNORMAL CHECKLIST.

**Item 3:** I fully agree; too high a noise level can even lead to a wrong decision.

**B.**

**Item 1/2:** I fully support the statement that too many aural warnings are used today.

Instead of repeating the tone once, twice or three times, I suggest that we look into the aural warning as used on the French Caravelle, e.g., I could think of using one tone for Level II, but a GING/GONG type tone for Level III, etc. I am pretty sure that this would be more suggestive than always repeating the same tone.

**Item 3-5:** No comment.

**Item 6:** During evaluation of the present warnings it also occurred to me that a discrete audio warning is in certain cases a must, e.g.,

- DH aural warning
- SELCAL
- CABIN to COCKPIT, etc.

Since these tones are routinely heard, the meaning is well understood.



## II LEVELS OF URGENCY

### A.

Item 1-4: I generally agree, but I suggest that the present philosophy of having a lot of recall or memory items should be reviewed. The only memory item we have retained at SWISSAIR is the EMERGENCY DESCENT. All other items may only be performed using the EMERGENCY Checklist except for the 2-man cockpit. Only this guarantees that the right action is performed in the correct sequence.

It may be worthwhile to convince the FAA to review their philosophy.

### B.

Item 1: Based on my experience, I think that it will be very difficult to delete the aural warning for DH, especially with regard to CAT II/CAT III A operation, where the DH is a very important element for decision making. Also Selcal as well as the Cabin to Cockpit call - even routine - calls for a discrete aural signal unless somebody has a really good solution.

Item 2: GPWS. If a warning occurs, this at least calls for investigation. Therefore, it might not be necessary to put logic in, in order to identify phase of flight. Of course this can differ from company to company and may also depend on whether the warning "TERRAIN" or the order "PULL-UP" has been selected.

Item 3: No comments.

Item 4: Agreed.

Item 5: The present used "over-limit" light in the respective engine instrument has been proved to be a good idea. So I think it could be deleted from the warning system.

Item 6: Needs further discussion.

## III INHIBIT AND OTHER LOGIC

A. + B. Agree.

## IV PRIORITIES

See comments on Tables.

## V OTHER UNRESOLVED ISSUES

A. Agreed; fortunately the newest brand of radio altimeters has a very high reliability and/or MTBF.

B. - E. Agree.

#### TABLE ONE

No comments at present.

#### TABLE TWO LEVEL III

(A) Stall: Aural warning is just enough. I don't think that voice warning and visual display are necessary.

The stall warnings today were mostly a result of improper crew procedure, e.g., flaps/slats retraction at wrong speed, erroneous approach speed, wrong configuration, etc., etc.

I suggest that the industry be invited to study a design which tackles the problem at its root, e.g., speed command system with floor speed for approach and take-off with full time redundant autothrottles as a standard equipment. Inhibit logic to avoid flaps/slats retraction at too slow speeds, etc.

I think that a lot of warnings could be eliminated if the system were to be properly designed.

(B) No comment.

(C) A/P - inadvertent disconnect (non red. system & below R/A)

During this phase of the flight the crew is much more alert than in cruise. Do we really need 3 tones/voice/visual display at this very critical point? If the answer is No, then we are back to a discrete autopilot disconnect signal - aural or visual!

#### TABLE THREE LEVEL II

--Over-rotation is another example where a speed command system for take-off may help. No warning but proper design!

--Otherwise no comments yet.

#### TABLE FOUR LEVEL I

No comments.

#### TABLE FIVE LEVEL 0

No comments.

## APPENDIX G

### APPLICATION OF ALERT PRIORITIZATION SCHEME TO A 737 AIRCRAFT

This appendix provides a tabulation of the priority levels that each alerting function on a 737 aircraft might be assigned by the proposed prioritization criteria. The alert levels specified for each flight phase correlate with the categories defined in table 14. A dash in these columns indicates that the alert is (1) not required in that flight phase or (2) should be inhibited in that flight phase.

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		GRD MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1500 TO 14,000 FT	ABOVE 14,000 FT	AFTER 1500 TO 200 FT	LOG	TAXI AND SHUT- DOWN
AIR CONDITIONING													
AIR CONDITIONING SYSTEM MALFUNCTION	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3
NO AIRFLOW IN COCKPIT OR EQUIPMENT COOLING COMPARTMENT	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3
EXCESSIVE DIFFEREN- TIAL PRESSURE	1 YELLOW/RED BAND	2	2	-	-	-	-	-	2	2	-	-	-
DUCT OVERHEAT	2 AMBER LIGHTS	2	2	2	2	3	-	-	2	2	3	-	3
OFF SCHEDULE DESCENT	1 AMBER LIGHT	2	3	-	-	-	-	-	3	3	-	-	-
OUTFLOW VALVES POSITION	1 BLUE LIGHT	4	4	4	4	-	-	-	4	4	4	-	4
PACK OVERHEAT/ TRIP OFF	2 AMBER LIGHTS	3	3	3	3	3	-	-	3	3	3	-	3
PRESSURIZATION FAILURE	1 AMBER LIGHT AND HORN	2	2	-	-	-	-	-	2	1	-	-	-
PRESSURIZATION SYSTEM OPERATING MODE	2 GREEN LIGHTS	4	4	-	-	-	-	-	4	4	4	-	-
RAM AIR DOOR OPEN	2 BLUE LIGHTS	4	4	4	4	-	-	-	4	4	4	-	4

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CARL MASTER	PRE- FLT	ENG ST.	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1500 TO 14,000 FT	ABOVE 14,000 FT	APPL 1500 TO 200 FT	LDC.	TAXI & SHUT- DOWN
AIRCRAFT GENERAL													
MASTER CAUTION	2 AMBER LIGHTS	2	2	2	2	-		-	2	2	2	-	2
ALTITUDE ALERT													
APPROACHING ALTITUDE	1 BLUE LIGHT & TONE	3	3	-	-	-		-	3	3	-	-	-
ALTITUDE ALERT FAILURE	1 RED FLAG	3	3	-	-	-		-	3	3	-	-	-
APU													
APU LOW OIL PRESS/ AUTO SHUTDOWN	1 AMBER LIGHT	3	3	3	3	-		-	2	2	2	-	3
APU OIL QUANTITY LOW	1 BLUE LIGHT	3	3	3	3	-		-	3	3	3	-	3
APU EGT OVERTEMP	1 GREEN/YELLOW/ RED BAND	3	3	3	3	-		-	3	3	3	-	3
APU OIL TEMP HI	1 AMBER LIGHT	3	3	3	3	-		-	3	3	3	-	3
APU FAILURE	1 AMBER LIGHT	3	3	3	3	-		-	3	3	3	-	3
APU OVERSPEED	1 AMBER LIGHT	3	3	3	3	-		-	3	3	3	-	3

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		GRD MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1500 TO 14,000 FT	ABOVE 14,000 FT	APPR 1500 TO 200 FT	LDG	TAXI AND SHUT- DOWN
<u>AUTOMATIC FLIGHT CONTROL SYSTEM</u>													
AUTOPILOT DISCONNECT	2 FLASHING RED LIGHTS	2	2	-	-	-	-	-	2	2	2	1	-
AUTOTHROTTLE DISCONNECT	2 RED LIGHTS (INOP)	2	2	-	-	-	-	-	2	2	2	1	-
FLIGHT DIRECTOR VOR/LOC CAPTURE MODE ARMED	2 AMBER LIGHTS	4	4	-	-	-	-	-	4	4	4	-	-
FLIGHT DIRECTOR- VOR COURSE/LOC CAPTURED	2 GREEN LIGHTS	4	4	-	-	-	-	-	4	4	4	4	-
FLIGHT DIRECTOR GLIDE SLOPE CAPTURE MODE ARMED	2 AMBER LIGHTS	4	4	-	-	-	-	-	4	-	4	-	-
FLIGHT DIRECTOR- GLIDE SLOPE CAPTURED	2 GREEN LIGHTS	4	4	-	-	-	-	-	4	-	4	-	-
AUTOPILOT VOR/LOC CAPTURE MODE ARMED	2 AMBER LIGHTS	4	4	-	-	-	-	-	4	4	4	-	-
AUTOPILOT VOR COURSE/LOC CAPTURED	2 GREEN LIGHTS	4	4	-	-	-	-	-	4	4	4	4	-
AUTOPILOT GLIDE SLOPE CAPTURE MODE ARMED	2 AMBER LIGHTS	4	4	-	-	-	-	-	4	-	4	-	-
AUTOPILOT - GLIDE SLOPE CAPTURED	2 GREEN LIGHTS	4	4	-	-	-	-	-	4	-	4	-	-
GO-AROUND MODE ENGAGED	2 GREEN LIGHTS	4	4	-	-	-	-	4	-	-	4	4	-

ALERTING FUNCTION	CURRENTLY USED TYPE - OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CSD MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB FT	1500 TO 14,000 FT	ABOVE 14,000 FT	APPR 1500 TO 200 FT	LOG	TAXI AND SHUT- DOWN
<u>COMMUNICATIONS</u>													
MICROPHONE/TRANS- MITTER COMBINATION SELECTED	15 GREEN LIGHTS	4	4	4	4	4	4	4	4	4	4	4	4
VHF COMM CHANNEL SELECTED BY TRANSFER SWITCH	6 GREEN LIGHTS	4	4	4	4	4	4	4	4	4	4	4	4
SELCAL ACTIVATED	2 GREEN LIGHTS AND CHIME	3	3	3	3	3	3	3	3	3	3	3	3
ATTENDANT CALL	1 BLUE LIGHT AND CHIME	3	3	3	3	-	-	-	3	3	3	-	3
<u>ELECTRICAL SYSTEMS</u>													
EXTERNAL POWER AVAILABLE	1 BLUE LIGHT	4	4	4	-	-	-	-	-	-	-	-	4
CSD OR IDG OIL TEMP HIGH	2 AMBER LIGHTS AND 4 YELLOW BANDS	2	2	2	2	-	-	-	2	2	2	-	2
CSD OR IDG OIL PRESSURE LOW	2 AMBER LIGHTS	2	2	2	2	-	-	-	2	2	2	-	2
GENERATOR BREAKER OR RELAY TRIPPED OPEN	2 BLUE LIGHTS	3	3	3	3	-	-	-	3	3	3	-	3
AC STANDBY BUS FAILED OR OFF	1 AMBER LIGHT	2	3	2	2	-	-	-	2	2	2	-	2
AC BUS OFF	2 AMBER LIGHTS	3	3	3	3	-	-	-	3	3	3	-	3

ALERT LEVEL AS FUNCTION OF FLIGHT PHASE													
ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	CRJ MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. BELL	FINAL T.O. BELL	INITIAL TO CLIMB	1500 TO 14,000 FT	ABOVE 14,000 FT	APPR 1500 TO 200 FT	LOG	TAXI AND SHUT- DOWN
(CONT) <u>ELECTRICAL SYSTEMS</u>													
	APU GENERATOR RELAY OPEN	3	3	3	3	-	-	-	3	3	3	-	3
	AC TRANSFER BUS OFF	3	3	3	3	-	-	-	3	3	3	-	3
ELECTRICAL SYSTEM FAULT	1 AMBER LIGHT	4	4	4	4	-	-	-	4	4	4	-	4
<u>EMERGENCY EQUIPMENT</u>													
PASSENGER OXYGEN SYSTEMS ON	1 AMBER LIGHT	2	2	2	2	-	-	-	2	2	2	-	2
OXYGEN FLOW— PRESSURE REGULATOR	3 WHITE FLAGS	4	4	4	4	4	4	4	4	4	4	4	4
EMERGENCY LIGHTS NOT ARMED	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3
<u>FIRE PROTECTION</u>													
MASTER FIRE WARNING	2 RED LIGHTS AND BELL	2	2	2	2	2	-	-	2	2	2	-	2
FIRE EXTINGUISHER BOTTLE DISCHARGED	3 AMBER LIGHTS	4	4	4	4	4	-	-	4	4	4	-	4
ENGINE OVERHEAT	2 AMBER LIGHTS	3	3	3	3	3	-	-	3	3	3	-	3



ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CBS BRIGHT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1500 TO 14,000 FT	ABOVE 14,000 TO 200 FT	APPR 1500 TO 200 FT	LDS	TAXI AND SHUT- DOWN
(CONT)													
<u>FIRE PROTECTION</u>													
ENGINE FIRE	2 RED LIGHTS	2	2	2	2	2	-	-	2	2	2	-	2
APU FIRE	1 RED LIGHT	2	2	2	2	2	-	-	2	2	2	-	2
WHEEL WELL FIRE	1 RED LIGHT	2	2	-	2	2	-	-	2	2	2	-	2
CARGO COMPARTMENT FIRE	2 RED LIGHTS	2	2	2	2	2	-	-	2	2	2	-	2
FIRE BOTTLE SOUNDS OK	3 GREEN LIGHTS	4	4	4	4	-	-	-	4	4	4	-	4
ENGINE OVERHEAT OR APU FIRE DETECTOR INOP	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3
APU FIRE DETECTION SYSTEM FAILURE	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3
<u>FLIGHT CONTROLS</u>													
STALL WARNING SYSTEM FAILURE	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3
STALL WARNING	STICK SHAKER	1	1	-	-	-	-	1	1	1	1	1	-
MACH TRIM FAIL	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3
LEADING EDGE FLAPS AND SLATS EXTENSION STATUS	12 GREEN AND 10 AMBER LIGHTS	4	4	4	4	4	-	4	4	4	4	-	4

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CAB INERT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1000 TO 1400 FT	ABOVE 1400 FT	APPR 1500 TO 200 FT	LDC	TAXI AND SHUT- DOWN
(CONT) FLIGHT CONTROL													
LEADING EDGE SLATS OR FLAPS IN-TRANSIT	1 AMBER LIGHT	4	4	4	4	-	-	-	4	4	4	-	4
LEADING EDGE SLATS FULLY EXTENDED	1 GREEN LIGHT	4	4	4	4	-	-	-	4	4	4	-	4
LEADING EDGE FLAPS FULLY EXTENDED	1 GREEN LIGHT	4	4	4	4	-	-	-	4	4	4	-	4
STABILIZER OUT-OF- TRIM	1 AMBER LIGHT	4	4	4	3	2	-	-	3	3	3	-	4
YAW DAMPER FAILURE	1 AMBER LIGHT	3	3	3	2	2	-	-	2	2	2	-	3
STABILIZER TRIM OPERATING	1 AMBER LIGHT	4	4	4	4	-	-	-	4	4	4	-	4
ELEVATOR HYDRAULICS LOW PRESSURE	2 AMBER LIGHTS	2	2	2	2	2	-	-	2	2	2	2	2
RUDDER HYDRAULICS LOW PRESSURE	2 AMBER LIGHTS	2	2	2	2	2	-	-	2	2	2	2	2
AILERON HYDRAULICS LOW PRESSURE	2 AMBER LIGHTS	2	2	2	2	2	-	-	2	2	2	2	2
FLIGHT CONTROL SYSTEM MALFUNCTION	1 AMBER LIGHT	3	3	3	3	3	-	-	3	3	3	-	3
RUDDER OR ELEVATOR FEEL DIFFERENTIAL PRESSURE EXCESSIVE	1 AMBER LIGHT	3	3	3	3	3	-	-	3	3	3	-	3

ALERTING FUNCTION	CURRENTLY USED TYPED OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CAB INHAUT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1500 TO 14000 FT	ARRIVE 14000 FT	APPR 1500 TO 200 FT	LDC	TAXI AND SHUT- DOWN
(CONT) <u>FLIGHT CONTROL</u>													
SPEED BRAKE— DO NOT ARM	1 AMBER LIGHT	2	2	-	-	-	-	-	2	-	2	-	-
SPEED BRAKE ARMED	1 GREEN LIGHT	3	3	-	-	-	-	-	3	-	3	3	-
UNSAFE TAKEOFF CONFIGURATION	INTERMITTENT HORN	1	1	-	3	1	-	-	-	-	-	-	-
<u>FLIGHT INSTRUMENTS AND AIR DATA</u>													
RADIO ALTIMETER FAIL	2 RED FLAGS	3	3	3	3	3	-	-	3	-	3	3	3
INSTRUMENT INDICATION COMPARISON	12 YELLOW LIGHTS AND CLACKER	3	3	3	3	3	-	-	3	3	3	-	3
INSTRUMENT COMPARISON MONITOR FAILURE	2 YELLOW LIGHTS	3	3	3	3	3	-	-	3	3	3	-	3
STATIC SOURCE ERROR CORRECTION FAILURE	2 BLACK FLAGS	3	3	3	3	3	-	-	3	3	3	-	3
BAROMETRIC ALTITUDE INFO FAIL	2 GREEN FLAGS	3	3	3	3	3	-	-	3	3	3	-	3
STANDBY ATTITUDE FAIL/OFF	1 RED FLAG	3	3	3	3	3	-	-	3	3	3	-	3
GROUND PROXIMITY WARNING	2 RED LIGHTS AND MESSAGE	1	1	-	-	-	-	1	1	1	1	1	-

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CAD MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	14,000 TO 14,000 FT	ABOVE 14,000 FT	APPR 1500 TO 200 FT	LDS	TAXI AND SHUT- DOWN
(CONT)													
FLIGHT INSTRUMENTS AND AIR DATA													
BELOW GLIDESLOPE WARNING	2 AMBER LIGHTS AND MESSAGE	2	2	-	-	-	-	-	-	2	3	-	-
GROUND PROXIMITY SYSTEM FAIL	1 AMBER LIGHT	3	3	-	-	-	-	-	3	3	-	3	-
DECISION HEIGHT	2 AMBER LIGHTS AND TONE	2	2	-	-	-	-	-	-	2	2	-	-
TOTAL AIR TEMP INDICATION BAD	1 RED FLAG	3	3	3	3	-	-	-	3	3	-	3	-
OVER OUTER MARKER	2 FLASHING BLUE LIGHTS AND TONE	4	4	-	-	-	-	-	4	-	-	-	-
OVER MIDDLE MARKER	2 FLASHING AMBER LIGHTS AND TONE	4	4	-	-	-	-	-	-	4	-	-	-
OVER AIRWAYS MARKER BEACON	2 FLASHING CLEAR LIGHTS	4	4	-	-	-	-	-	4	4	-	-	-
EXCESSIVE AIRSPEED OR MACH	CLACKER	2	2	2	2	-	-	-	2	2	-	-	-
FUEL													
ENGINE FUEL SHUTOFF VALVE IN-TRANSIT	2 BRIGHT BLUE LIGHTS	4	4	4	4	-	-	-	4	4	-	4	-
ENGINE FUEL SHUTOFF VALVE CLOSED	2 DIM BLUE LIGHTS	3	3	3	3	2	-	-	3	3	-	3	-

ALERTING FUNCTION		CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE										
			GND MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL TO CLIMB	1500 TO 14,000 FT	ABOVE 14,000 FT	APPR 1500 TO 200 FT	LOG
(CONT) FUEL													
FUEL BOOST PUMP LOW PRESSURE	6 AMBER LIGHTS	3	3	3	3	3	-	-	3	3	3	-	3
CROSSFEED VALVE IN-TRANSIT	1 BRIGHT BLUE LIGHT	4	4	4	4	4	-	-	4	4	4	-	4
CROSSFEED VALVE OPEN	1 DIM BLUE LIGHT	4	4	4	4	4	-	-	4	4	4	-	4
FUEL FILTER ICING	2 AMBER LIGHTS	2	2	2	2	2	-	-	2	2	2	-	2
FUEL HEAT VALVE IN-TRANSIT	2 BRIGHT BLUE LIGHTS	4	4	4	4	-	-	-	4	4	4	-	4
FUEL HEAT VALVE OPEN	2 DIM BLUE LIGHTS	4	4	4	4	-	-	-	4	4	4	-	4
FUEL SYSTEM MALFUNCTION	1 AMBER LIGHT	3	3	3	3	3	-	-	3	3	3	-	3
HYDRAULIC POWER													
ENGINE DRIVEN PUMP OUTPUT PRESSURE LOW	2 AMBER LIGHTS	3	3	3	3	-	-	-	3	3	3	-	3
HYDRAULIC PUMP CASE DRAIN FLUID TEMP HIGH	2 AMBER LIGHTS	3	3	3	3	-	-	-	3	3	3	-	3
STANDBY SYSTEM HYDRAULIC FLUID QUANTITY LOW	1 AMBER LIGHT	3	3	3	3	-	-	-	3	3	3	-	3

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		GRD MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL TO CLIMB FEET	1500 TO 14,000 FEET	ABOVE 14,000 FEET	APPR 1500 TO 200 FT	LOG	TAXI AND SHUT- DOWN
(CONT) HYDRAULIC POWER													
ELECTRIC DRIVEN PUMP—LOW OUTPUT PRESSURE	2 AMBER LIGHTS	3	3	3	3	—	—	—	3	3	3	—	3
HYDRAULIC SYSTEM MALFUNCTION	1 AMBER LIGHT	3	3	3	3	3	—	—	3	3	3	—	3
HYDRAULIC PRESSURE ABNORMAL	1 GREEN, 2 YELLOW AND 1 RED BAND	3	3	3	3	—	—	—	3	3	3	—	3
STANDBY HYDRAULIC PUMP—LOW PRESSURE	1 AMBER LIGHT	3	3	3	3	—	—	—	3	3	3	—	3
ICE AND RAIN PROTECTION													
PITOT HEAT ON	7 GREEN LIGHTS	4	4	4	4	—	—	—	4	4	4	—	4
WING ANTI-ICE VALVE IN-TRANSIT	2 BRIGHT BLUE LIGHTS	4	4	4	4	—	—	—	4	4	4	—	4
WINDOW OVERHEAT	4 AMBER LIGHTS	3	3	3	3	—	—	—	3	3	3	—	3
WINDOW HEAT ON/OFF	4 GREEN LIGHTS	4	4	4	4	—	—	—	4	4	4	—	4
WING ANTI-ICE VALVE OPEN	2 DIM BLUE LIGHTS	4	4	4	4	—	—	—	4	4	4	—	4
ENGINE ANTI-ICE VALVES IN-TRANSIT	6 BRIGHT BLUE LIGHTS	4	4	4	4	—	—	—	4	4	4	—	4
ENGINE ANTI-ICE VALVES OPEN	6 DIM BLUE LIGHTS	4	4	4	4	—	—	—	4	4	4	—	4

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE										
		GRD MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1500 TO 14,000 FEET	ABOVE 14,000 TO 200 FT	LDG	TAXI AND SHUT- DOWN
(CONT)												
ICE AND RAIN PROTECTION												
ANTI-ICE SYSTEM MALFUNCTION	1 AMBER LIGHT	3	3	3	3	-	-	3	3	3	-	3
LANDING GEAR												
GEAR DOWN AND LOCKED	3 GREEN LIGHTS	3	3	3	3	-	-	3	3	3	3	3
ANTI-SKID FAILURE	2 AMBER LIGHTS	3	3	3	3	-	-	3	3	3	3	3
ANTI-SKID OFF	2 AMBER LIGHTS	4	4	4	4	-	-	4	4	4	4	4
BRAKE PRESSURE ABNORMAL	1 GREEN, 1 YELLOW AND 2 RED BANDS	2	2	2	2	2	-	2	2	2	2	2
PARKING BRAKES ON	1 RED LIGHT	2	2	2	2	2	-	-	-	-	-	2
GEAR COMPARTMENT NOT SEALED	1 AMBER LIGHT	3	3	-	-	-	-	3	3	-	-	-
GEAR NOT DOWN AND LOCKED AND THRUST LEVER AT IDLE	3 RED LIGHTS AND HORN	2	2	-	-	-	-	2	2	2	2	-
GEAR UNLOCKED	3 RED LIGHTS AND HORN	2	2	2	2	2	2	2	2	2	1	2
GEAR DOWN AND LOCKED BUT LEVER NOT IN DOWN DETENT	3 RED LIGHTS AND HORN	1	1	1	1	1	-	-	-	1	1	1
EQUIPMENT TIRE BURST	1 AMBER LIGHT	2	2	-	-	-	-	2	2	2	2	2

ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CRD MAINT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	1500 TO 14,000 FEET	ABOVE 14,000 TO 200 FT	APPS 1500 TO 200 FT	LOG	TAXI AND SHUT- DOWN
(CONT)													
<u>LANDING GEAR</u>													
UNSAFE LANDING CONFIGURATION	HORN	1	1	-	-	-	-	-	-	1	1	-	-
<u>NAVIGATION</u>													
FLIGHT DIRECTOR INFO FAIL	2 RED FLAGS	3	3	3	3	3	-	3	3	3	3	3	3
GYRO FAILURE	2 RED FLAGS	2	2	2	2	2	-	2	2	2	2	2	2
COMPASS SYSTEM FAILURE	4 RED FLAGS	3	3	3	3	3	-	3	3	3	3	3	3
AUXILIARY VERTICAL GYRO INOP	1 WHITE FLAG	3	3	3	3	-	-	-	3	3	3	-	3
TRANSPONDER IN TEST MODE	1 GREEN LIGHT	4	4	4	4	-	-	-	4	4	4	-	4
LOCALIZER INFO FAIL	2 RED FLAGS	3	3	3	3	-	-	-	3	3	3	3	-
VOR INFO FAIL	2 RED FLAGS	3	3	3	3	3	-	-	3	3	3	-	-
GLIDE SLOPE INFO FAIL	2 RED FLAGS	3	3	3	3	-	-	-	3	-	3	3	-
<u>PNEUMATICS</u>													
BLEED AIR TEMP HIGH	2 AMBER LIGHTS	2	2	2	2	-	-	-	2	2	2	-	2
BLEED TRIP OFF	2 AMBER LIGHTS	3	3	3	3	-	-	-	3	3	3	-	3



ALERTING FUNCTION	CURRENTLY USED TYPE OF ALERT	ALERT LEVEL AS FUNCTION OF FLIGHT PHASE											
		CAB BAPT	PRE- FLT	ENG ST	TAXI	INITIAL T.O. ROLL	FINAL T.O. ROLL	INITIAL CLIMB	ESB TO FLYING FEET	ABOVE 14,000 FEET	APPR 500 TO 200 FT	LDG	TAXI AND SHORT- STOP
(CONT)													
PNEUMATICS													
DUAL BLEED SOURCES	1 AMBER LIGHT	3	3	2	3	-	-	-	3	3	3	-	3
POWER PLANT													
REVERSER ACCUMULATOR PRESSURE LOW	1 AMBER LIGHT	2	2	2	2	-	-	-	2	-	2	2	2
N2 OVERSPEED	2 GREEN/YELLOW/ RED BANDS	2	2	2	2	2	-	-	2	2	2	-	2
N1 OVERSPEED	2 GREEN/YELLOW/ RED BANDS	2	2	2	2	2	-	-	2	2	2	-	2
EPR INDICATION FAIL	1 RED FLAG	2	2	2	2	2	-	-	2	2	2	-	2
EGT OVERTEMP	2 GREEN/YELLOW/ RED BANDS	2	2	2	2	2	-	-	2	2	2	-	2
OIL TEMPERATURE HIGH	2 GREEN/YELLOW/ RED BANDS	2	2	2	2	2	-	-	2	2	2	-	2
OIL FILTER CLOGGED	2 AMBER LIGHTS	3	3	3	3	3	-	-	3	3	3	-	3
ENGINE OIL PRESSURE LOW	2 AMBER LIGHTS PLUS 2 GREEN/ YELLOW/RED BANDS	2	2	2	2	2	-	-	2	2	2	-	2
REVERSER UNLOCKED	2 AMBER LIGHTS	3	3	3	3	3	-	-	3	3	3	3	3
REVERSER ARMED	1 BLUE LIGHT	3	3	3	3	3	-	-	3	3	3	3	3

## APPENDIX H

### TABULATION OF ABSTRACTS FROM HUMAN FACTORS PAPERS RELEVANT TO ALERTING SYSTEMS AS A FUNCTION OF DIRECT APPLICABILITY

Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil std/ guide no.	Military standard/design guideline
Visual signals - size	Elliott 1968	For a simple reaction time* (RT) task, the RT for a 10° visual angle light was no different than for a 30° light.  *Simple reaction time is the time to react to a stimulus when that is the only task to be accomplished.	Merriman 1969	Reaction time to Grimes warning lights (1.8" x 7/10" legend with border illumination) decreased as the width of the border illumination leveled off at .75 sec for a width of 1/4".	MIL STD 411D	<ul style="list-style-type: none"> <li>A 3/16 inch border shall surround legends</li> </ul>
	Freuberg 1907	Simple RT decreased as the size increased leveling off at 20° visual angle	Sheehan 1972	Response times to alphanumeric legends decreased as size increased leveling off at 1 sec for 10° visual angle		
Visual signals - brightness and contrast	Pabb 1962	Simple RT decreased as brightness increased leveling off at 180 msec for 30 ft L. Signal size was 10° min of visual angle. Lighted signal was presented in a dark room			MIL STD 411D	<ul style="list-style-type: none"> <li>The legend on a signal when energized shall be readable under direct sunlight (10,000 ft L). When not energized the legend should not be readable and shall not appear energized in direct sunlight.</li> </ul>
	Rains 1962	Found that a 1.59 mL signal with a 4 minute visual angle and a .023 sec flash was the detection threshold for a white signal in a simple RT task. Lighted signal was presented in a dark room				<ul style="list-style-type: none"> <li>Brightness shall be no less than 150 ft L. Warning lights should be dimmed to 15x3 ft L when the pilots primary instrument light control is "on". Advisory lights should be dimmed to 145 ft L, when the primary light control is at max. intensity.</li> </ul>
	Kohlsted 1971	Simple RT decreased as intensity increased leveling off at 220 msec between 1 and 100 mL for white light. Signal was presented in a dark room			MIL STD 1472B	<ul style="list-style-type: none"> <li>Brightness of rear lighted displays shall be at least 10x greater than the brightness of the area around the display. A dimming control should be provided.</li> </ul>
	Howland 1936	Found that for moderate brightness levels there was no relationship between brightness and RT except for completely dark adapted subject who reacted to a 250 ft C signal faster			MIL C 81774A	<ul style="list-style-type: none"> <li>Contrast between lighted and unlighted portions of a display, under high ambient illumination (10,000 ft C) shall be a minimum of 3 when calculated as:  <math display="block">C = \frac{E_1 - B_2}{B_1} = \frac{\text{Brightness of illuminated portion}}{\text{Brightness of unlighted portion}}</math> </li> </ul>
	Matteson 1971	A low level of brightness of the area surrounding the signal caused a small decrease in RT (25 msec) over no surrounding light. There was no further effect of surround on RT until the surround became brighter than the signal				
	Techner 1954	Simple RT decreased as intensity increased leveling off at 25 ft C for larger objects (3.5 2 minutes visual angle) and 45 ft C for smaller objects (1.2 minutes)				
	Gerathewohl 1953	Flashing signals produced faster RT (2 sec) than steady signals when contrast levels were less than one. For levels greater than one there was no significant difference between the signal for the lowest contrast (Signal Luminance / Background Luminance) Level 1.5; the average number of misses for the steady signal was 50, and for the flashing signal was 5.				
Visual signals - location	Coates 1972	For binocular viewing simple RT was fastest at the middle position +40° for the gating scan pattern and at +240° for the scanning pattern	Rich 1971	Using very small (6 minutes visual angle) stationary targets 83% were detected when the target was on the line of sight and 35% when it was 30° to 40° left or right	MIL STD 411D	<ul style="list-style-type: none"> <li>Nominal envelope of vision for both pilot and copilot is a 30° cone symmetrical about a line from eye position to the top of the instrument panel</li> </ul>

Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil std/ guide no.	Military standard/design guideline
Visual signals - location (cont)	Rains 1962	Simple RT for the right eye was fastest at 0° and increased as the horizontal angle increased. It had not leveled out at 30°. Signals to the left produced faster RT's than to the right and signals above horizontal produced faster RT's than those below.	Siegel 1960	Found that response to signals located at 0° horizontal displacement from pilot's centerline of vision was faster than to signals located at either 33° or 95°. Mean response time for signals at 95° was 1.2 seconds slower than for signals at 0°.		<ul style="list-style-type: none"> <li>Light signals shall not be located within the pilots or copilots basic flight instrument group. When warning lights have to be located outside the 30° cone of vision a master signal must be provided within the cone.</li> </ul>
	Sharp 1967	Using a sound as a cue for a visual signal found no difference in visual RT as the horizontal displacement of the signal increased from 0° to 75°.				<ul style="list-style-type: none"> <li>Except where specifically authorized advisory lights shall not be located on the main instrument panel.</li> </ul>
	Sharp 1968	For visual RT with no auditory cue there was an increase in the RT variable as the horizontal displacement of the signal increased from 57° to 83°. However, the mean RT did not change over this range. The RT increased sharply at displacements greater than 83° and 96°. 75 percent of the signals were missed entirely.			MIL-STD 1472B	<ul style="list-style-type: none"> <li>Viewing distance from eye reference to display shall not be less than 13 inches preferably, not less than 20 inches or greater than 28 inches.</li> </ul>
	Haines 1975	Described zones of equal RT for different colored signals. The lowest RT zone (330 msec) for red lights covered a signal displacement of 30° left, 35° right, 20° up and 25° down. The lowest RT zone (270 msec) for white lights was from 45° left to 50° right and 20° up to 25° down.				
	Teicher 1954	Simple RT to a white light increased from .004 sec at 30° horizontal displacement from the centerline of vision to .024 sec at 45°.				
Visual signals - format	Crawford 1962	Used white signals with red and green distractors. Found no difference in a simple RT task between steady and flashing signals with no distractors. Flashing signals with steady distractor produced fastest RT.	Noble 1958	Alternating and flashing lights produced superior detection (not qualified) on both day and night conditions. If a steady light was missed it was more likely to remain missed.	MIL-STD 111D	<ul style="list-style-type: none"> <li>Flashing light presentation shall have flash rates of 3 to 5 per second. The "on" time shall be approximately equal to the "off" time.</li> </ul>
	Graflewahl 1953	Flashing signals produced a faster response time (by 2 sec) when contrast levels were less than one. For levels greater than one there was not a significant difference in response time to flashing and steady signals.				
	Edwards 1971	Built a reliable statistical model taking into account position (compared to class by flashing light of various characteristics) in order of their attention attracting value.				
Visual signals - color	Coates 1972	Red lights were detected significantly faster than green in a vigilance task. However the difference was only 17 msec.			MIL-STD 111D	<ul style="list-style-type: none"> <li>Warning signals will have red background with chequer letters. Caution signals will have yellow letters with opaque background. Advisory signals will have green or blue or white letters on an opaque background.</li> </ul>
	Jones 1960	Color coding is not suited for situations that demand rapid and precise detection but it is valuable in tasks that require a "qualitative" priority.			MIL-C 25050A	<ul style="list-style-type: none"> <li>Red lights shall not be yellowed nor less saturated than the light transmitted by an NBS 3215 filter from a 2854°K source. Other colors are given as coordinates of the CIE chromaticity diagram.</li> </ul>
	Wernigarten 1972	Simple RT to a red light was significantly faster than to a green one. However the difference was only 25 msec.				
	Haines 1973 1975	In a simple RT task the RT to a red light was 16.0 slower than to green or yellow lights. RT was significantly slower (up to 28%) in the peripheral field. Red signals were affected more by displacement than the others in both RT and noise. The fastest RT (288 msec) was for yellow signals. 150 RT maps are provided for each color for the full visual field.				

Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil std/ guide no.	Military standard/design guideline
Visual signals - color (cont)	Pollack 1988	The effect of color on RT decreased as brightness increased and there is relatively little effect due to color above 0023 ft. L. For brightnesses where there was an RT difference due to color RT's increased as the spectrum went from blue to red.				
	Bartlett 1968	Simple RT to red signals was significantly faster at the line of sight than at a displacement of 120 horizontally.				
	Warm 1967	In a simple RT task during vigilance the RT to signal offset was faster than to onset. There was no difference in RT between red and green signals.				
	Reynolds 1972	Performed simple response time task varying signal color, background color, and ambient light level. A red signal on blue background with dim ambient resulted in the fastest response time (1 sec). Response time for red was the fastest (2.019 sec). The other colors were as follows: green 2.341 sec., yellow 2.092 sec. and white 3.93 sec. Results indicate that red signals attract the greatest amount of attention.				
	Hill 1947	Detection thresholds for red, white, yellow and green lights were nearly equal over a range of background luminance from 10 <sup>-6</sup> to 10 <sup>-4</sup> ft. C.				
Visual signals - workload, fatigue, and vigilance	Singleton 1953	Response time in a 4 choice task increased significantly from the first to the second half of the trials during a 1 hour test period.	Adams 1961	Contrary to experiments with only a single stimulus source there was no decrement in percent correct over a 3 hr period for more complex tasks (6 or 36 stimuli). Response latency declined significantly for the single stimulus task and not at all for the complex tasks.		
	McComack 1960	Simple RT increased significantly throughout a 30 minute task.				
	Malinski 1970	Simple RT showed an immediate increase with physical exercise.				
	Crawford 1962	Found that simple RT doubles when going from 0 to 10 distractors (8 to 15 sec) and trebles when going to 21				
	Teichner 1974	Loss of detection performance on displays requiring no eye movement was relatively small over the 3 hour vigilance period.				
	Poulton 1966	Detection performance during vigilance will be better if the pilot's senses are kept active or if he is a member of a team.				
	Hyman 1952	Simple RT to a given signal increased as the information in the signal increased. A linear function was described for the relationship between RT and signal information (0 to 3 bits).				
	Bowen 1964	For a high probability event (20 hr) the RT (7 sec) was less affected by the time on the task than the RT (14 sec) for low probability events (1 hr).				
	Ware 1966	Detection decreased from 85 to 65 percent when going from 1 to 4 signal sources and a 5 to 10 percent decrease was observed over a 3 hr period for all conditions.				

Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil std/ guide no.	Military standard/design guideline
Visual signals - pilot age	Tolin 1968	Older subjects (66-87 years) exhibited a 30% slower RT and a 76% slower movement time. Increasing the task complexity did not have a differential effect for RT but the older subjects did show increasingly slower movement times.				
	Szalran 1969	Visual accommodation drops from 6 diopters in younger pilots (30) to 4 diopters in older pilots (45). Flash rate fusion frequency reaches a minimum at age 35 and increases with age. There is no evidence of change in dark adaptation. Information processing, effective auditory threshold or auditory detection.				
	Talland 1966	Percent correct detections decreased significantly (10 to 15%) with age for a range of signal durations from 5 to 3 seconds.				
	Teicher 1954	Simple RT decreases to age 30 then increases. However, at age 60 it was still faster than at age 10.				
	Rabbitt 1967	Subjects over the age of 60 do not get as much advantage out of redundant information as the 17-28 year olds.				
Visual signals - legend characteristics	Van Laer 1961	Visual acuity is satisfactory at brightness levels of .1 to .01 m/L in a dark room.	Siegel 1960	Dark legend on luminated background was superior in both RT and accuracy to luminated legend on dark background. For dark legends with a height-width ratio of 5:3 1/4 in. height was superior to 1/8 in. but the same as 3/8 in. for a 28 in. viewing distance.	MIL STD 4110	<ul style="list-style-type: none"> <li>For warning signals use a red background with opaque letters, for caution signals use yellow letters on an opaque background and for advisory signals use green, blue or white letters on an opaque background.</li> <li>Legends shall be 1/8 to 1/4 inch high. A 3/16 border should surround the legend.</li> </ul>
	Taylor 1961	Near threshold legends must be within 10° of direct line of sight. Legends must be twice threshold size when the displacement angle gets to 40°.	Bendix 1959	For dark legend on luminated background a bold character with a stroke width of 1/5 of the height should be used. For lighted legends a medium to light character style with stroke widths of 1/8 - 1/10 of the height should be used.		<ul style="list-style-type: none"> <li>Width of letters shall be 3/5 of the height except for "i", which shall be one stroke in width and the "m" and "w" which shall be 4/5 the height. Stroke width of the characters shall be 1/7 of the height.</li> </ul>
	Peters 1959	Developed a height formula for legends where $H = 0.022D + K_1 + K_2$ $H$ = Height in inches $D$ = Viewing distance $K_1$ = Correction factor for illumination & viewing conditions $K_2$ = Correction for importance	Brown 1953	The optimum height width ratio for transilluminated legends is 1:1 for uniform stroke block letters. The width should be no less than 2/3 the height use 9/64 in. height for the bulk of legends and 11/64 for emphasis for 28 in. viewing distance.	MIL C 81774A	<ul style="list-style-type: none"> <li>With a 28 inch viewing distance legend height shall be between .15 and .30 inches except critical markings which shall be no less than .2 inches. Width shall be 3/5 the height except "g" which shall be one stroke wider and "i" and "l" which shall be one stroke wide.</li> </ul>
			White 1960	At 28 in. viewing distance for critical markings legends height should be from .15 to .3 in. in low brightness (down to .03 ft L) 4.1 in. to 2 in. in high brightness (down to 1.0 ft L) and for non critical markings it should be from .05 in. to .2 in. in any brightness.	MIL M 18012B	<ul style="list-style-type: none"> <li>Stroke width shall be from 1/8 to 1/6 of the height and shall be uniform.</li> </ul>
			Atkinson 1952	NAMES style of legend produced fewer reading errors than either the Berger or the AN-1 style.	MIL M 18012B	<ul style="list-style-type: none"> <li>There shall be one stroke width between letters in a word and one letter width between words.</li> </ul>
			Van Cott 1972	When legend is used to report status the legend should be lighted and the background dark.		
Memory for signals	King 1963	Found in 3 experiments that subjects could reproduce brightness, flash rate and duration up to 28 days after seeing the standard with little difference from a reproduction made 2 min. after seeing the standard signal. However, only brightness was not significantly different from the standard.				

Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil STD/ guide no.	Military standard/design guideline
Auditory signals - format	Howarth 1961	A person has a lower recognition threshold to his own name than to other names	Pollack 1958	Voice warning was superior to a buzzer in time to identify a malfunction. Voice warning was superior even when extraneous messages were presented	MIL STD 4110	<ul style="list-style-type: none"> <li>• A non verbal audio master warning signal should (1) sweep from 700 cps to 1700 cps in 85 sec (2) have interation interval of 12 sec (3) repeat until unit is de-energized. Actual signal specs are given in the standard for specific events</li> <li>• Voice messages shall be used only for "hazardous or imminent catastrophic conditions requiring immediate action". They shall only be used in conjunction with red warning signals. They shall always start at the beginning of the message</li> </ul>
	Murray 1959	When attending to one ear, a person can pick up messages in the other ear, if the message is preceded by his name	Siegel 1960	A two tone master signal was superior to a single tone		<ul style="list-style-type: none"> <li>• Voice messages shall be used only for "hazardous or imminent catastrophic conditions requiring immediate action". They shall only be used in conjunction with red warning signals. They shall always start at the beginning of the message</li> </ul>
	Keuss 1972	By varying the intensity and interstimulus intervals of two auditory signals, found that simple RT to the second signal decreased leveling off at an 85 dB intensity and a 200 msec interval	Simpson 1975	Familiarity with phraseology contributes to intelligibility. Pilots scored 96.4% correct on a synthesized speech system	MIL STD 14728	<ul style="list-style-type: none"> <li>• Audio warning signals should normally consist of 2 elements, an alerting signal and an action signal. With a two element signal a 5 sec alerting tone shall be provided. If speed is essential all information should be transmitted in the first 2 seconds for a single element this time should be 5 sec</li> </ul>
	Gruenewald 1963	Auditory signals that are judged pleasant always give a slower RT than those judged unpleasant. There is an inverse relationship between RT and the number of ready signals (pleasant signals)	Thurber 1971	Experienced 358 pilots felt that a voice warning system contributes to flight safety, it reduces pilot workload		<ul style="list-style-type: none"> <li>• Tone frequency shall be between 200 and 5000 cps and shall be different from electrical power sounds in the system</li> </ul>
Auditory signals - workload, fatigue and vigilance	Holmuth 1970	When an auditory and visual vigilance task are performed simultaneously the performance on the primary visual task is not affected by the secondary auditory task. However, performance on a primary auditory task is affected by a secondary visual task	Kendler 1959	Voice warning system allowed the pilot to analyze the situation without bringing his visual attention into the cockpit		<ul style="list-style-type: none"> <li>• Verbal signals shall consist of an initial alerting signal and a brief standardized speech message</li> </ul>
	Zwolski 1958	Deterioration of the auditory threshold is linear with regard to the square of the time on the task				<ul style="list-style-type: none"> <li>• For verbal systems a message priority system shall be established and more critical messages shall over rule less critical ones</li> </ul>
	McGrath 1965	Signal detection (recognition of change in signal state) decreased over a 90 min. period for both easy and hard auditory signals				
	Davenport 1968	By increasing either signal duration or intensity the detection performance could be improved over an 80 min. test. General detection performance degraded with time				
	Alluris 1963	Even with high multiple task auditory vigilance performance declined as number of missed signals increased over a 4 hour period				
	Pope 1962	Found no correlation between subjects' visual and auditory vigilance performance				

Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil std/ guide no.	Military standard/design guideline
Auditory signals - loudness and ambient noise	Egan 1950	Gives curves that show the masking effect of a 400 cps tone and a 90 cps band of noise at different levels of intensity	Webster 1964	When either the speaker (in cockpit) or the listener (earphones) are in quiet, satisfactory intelligibility has been obtained to 125 dB jet noise. Good intelligibility has been obtained in noise by using a wide speech band width (3 octaves) centered between 1000 cps and 1800 cps, using minimum or no sidetones, conforming AVC circuit to preferred listening levels, peak clipping of 12 dB at maximum power, having a flat response and minimum distortion in audio circuitry	MIL STD 14728	<ul style="list-style-type: none"> <li>A signal to noise ratio of at least 20 dB shall be provided</li> </ul>
	Fletcher 1933	Presents a definition of loudness and techniques for measuring it. Gives equal loudness contours for different frequencies. Demonstrates how to calculate the loudness of a complex tone				<ul style="list-style-type: none"> <li>Verbal alarms for critical functions shall be at least 20 dB above the speech interference level</li> </ul>
	Hinch 1950	When speech and noise are presented simultaneously, the lowest threshold to the speech occurs when the speech is presented directly to an ear and the noise is separated by at least 90°	Van Catta 1972	A sound signal should exceed its masked detection threshold by at least 15 dB and the optimum sound level in noise is half-way between the masked threshold and 110 dB		<ul style="list-style-type: none"> <li>Volume shall be designed to be controlled by the operator</li> </ul>
	Kohfeld 1969	Simple RT is inversely related to the intensity of a ready signal				
Auditory signals - disruptive effects	Hartum 1973	Target detection deteriorated significantly in a 60-85 dB noise. A sorting task was not affected. When difficulty was rated both tasks were rated more difficult with noise	Kenneth 1969	Pilot presented a tone warning scanned the annunciator panel to determine the severity of the problem where those with a voice system did not have to	MIL STD 14728	<ul style="list-style-type: none"> <li>Audio signals should not be of such intensity as to cause discomfort or "ringing" in the ears as an after effect</li> </ul>
	Glass 1972	Performance is less disrupted when the noise is seen as necessary				<ul style="list-style-type: none"> <li>When audio signals delivered to a headset might mask other essential audio information separate channels may be provided</li> </ul>
Auditory signals - one vs two ears	Cherry 1953	Selective attention can be exhibited with very high accuracy when different information is presented to each ear. Subjects did not detect a language change in the rejected ear but they did detect a change from male to female and from speech to a tone. They had no trouble switching attention from ear to ear			MIL STD 14728	<ul style="list-style-type: none"> <li>When earphones are worn a dichotic presentation should be used when feasible, alternating the signal from ear to ear</li> </ul>
	Egan 1954	When presenting a message and a distractor the message can be 30 dB less intense when each is presented to a different ear than when they are both presented to the same ear				
	Gopher 1971	During selective attention there are significantly more intrusions from the interfering ear when it is the right ear than when it is the left. There is no difference in omissions				
	Poulton 1953	When a message and distractor are presented simultaneously the predominant mistake is misreading				
Auditory signals - signal number and memory effects	Miller 1956	For a signal that varied only in one dimension (frequency, intensity, duration, etc.) only 7 - 2 signals could be identified accurately				<ul style="list-style-type: none"> <li>When several different audio signals are to be used to discriminate differences in intensity, pitch, etc. shall be provided. If absolute discrimination is required the number of signals shall not exceed 5</li> </ul>
	Pollack 1952	A trained listener can identify 40-60 sounds presented individually. However, subjects could only identify 5 tones which differed only in frequency				
	Schulman 1970	When looking at the slope (m) of the line formed by relating the probability of false alarms to the probability of signal detection it was found that m increases with the increase in the probability of signal occurrence				



Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil std/ guide no.	Military standard/design guideline
Auditory signals - signal number and memory effects (cont)	King 1963	Found in 3 experiments that subjects could reproduce loudness, frequency and duration up to 28 days after hearing the standard sound with little difference from a reproduction produced 2 min. after hearing the standard sound. However, all reproductions were significantly different from the standard.				
Auditory signals - effects of pilot age	ASA 1954	One of the more reliable signs of aging in males is a progressive loss of hearing in higher frequencies.				
Bimodal presentation visual and auditory	Klemmer 1958	Found no difference in the accuracy of response to three tones or 3 colored lights. When tone and light were presented simultaneously accuracy increased from 84% to 95%. Performance declined if senses were alternated faster than once every 2 seconds.	Bate 1969	Median response time was fastest to a tone visual warning signal (1.7 sec) and slowest to a visual signal (4.5 sec).		<ul style="list-style-type: none"> <li>When used with a visual display and signals should be supplementary or supportive in nature</li> </ul>
	Morrell 1967	Simple RT to a visual signal decreased when the time between the visual signal and a following auditory signal decreased from 120-20 msec.	Siegel 1960	The fewest number of warning signals were missed when visual and auditory signals were presented together. For the individual signals auditory was superior to visual.		
	Morrell 1968	Simple RT was faster over a wider range of interstimulus intervals when the sequence was visual-auditory than when it was the reverse.	Bate 1967	Response time to a tone visual warning signal was faster (6.7 sec) than to a visual signal (7.8 sec). However, missed targets in the primary task were much less for the voice (74) or tone visual (83) systems than for the straight visual (111).		
	Perriment 1969	In Bimodal presentations simple RT was faster when the two signals came from the same side.				
	Doumas 1969	Simple RT to a visual signal was fastest with a preceding tone of 400 msec length. RT was also inversely related to the intensity of the auditory signal.				
	Fidell 1969	Simultaneous presentation of visual and auditory signals improved detection sensitivity as much as 3 dB.				
	Cablewiczawa 1963	Simple RT is directly related to the interval between visual and auditory signals. A 5 sec interval produced the fastest RT when the auditory signal precedes the visual.				
	Klingberg 1962	The probability of signal detection was significantly higher with a bimodal presentation. Detection was superior for auditory signals. Bimodal detection was the only task that did not deteriorate over the 1 hour test period.				
	Buckner 1963	Simultaneous presentation of visual and auditory signals improved detection probability during prolonged vigilance.				
	Carroll 1973	Simple visual RT decreased from 49 sec to 27 sec with the introduction of a 60 dB tone.				
	Bertelson 1968	Simple RT to a visual signal decreased when preceded by a click (RT = 270 msec with a 20 msec interval and RT = 240 msec with a 150 msec interval). Simultaneous presentation produced a faster (20 msec) RT than no click.				
Tactile signals - detectability	Geldard 1957	The lowest vibration detected 100% of the time was 50 micrometers. In a range from 50-400 micrometers 3 levels can be identified.				

Area of concern	Author	Nonaircraft related test data findings	Author	Aircraft related test data findings	Mil std/ guide no.	Military standard/design guideline
Tactile signals - detectability (cont)	Geschneider	The intensity of vibrotactile signal is directly related to probability of detection and inversely related to RT.				
	Hill 1968	Tactile displays were correctly interpreted more often when their location was on a body part not involved in motion.				
	Shiffrin 1974	Performance was not reduced when 3 senses are used simultaneously for signals as compared to using senses individually.				
	Swets 1969	d' for a vibrotactile signal is linearly related to signal intensity.				
Tactile signals - effectiveness	Johnston 1972	Simple h <sub>v</sub> was fastest to tactile signal under all work load conditions.				
	Davenport 1969	Bimodal presentation of auditory and tactile signals was superior to either individually. Auditory was superior to tactile.				
	Loeb 1962	Auditory signals were superior to tactile in both number of misses and RT. Tactile signals were more affected by vigilance.				
Tactile signals - signal number	Diespecker 1969	Subjects were able to learn a 9 element 13 intensities and 3 durations code and perform over a range of durations.				

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## APPENDIX I

### TEST PLANS FOR ADDITIONAL HUMAN FACTORS TESTS REQUIRED TO COMPLETE DEFINITION OF AND VALIDATE RECOMMENDED ALERTING SYSTEM DESIGN STANDARDS

**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION - VISUAL SYSTEMS

**VARIABLES:** SIGNAL BRIGHTNESS x SIGNAL STYLE x PILOT WORKLOAD x AMBIENT LIGHT LEVEL

**PROBLEM:** The effectiveness of any visual caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal brightness, signal style, pilot workload and ambient light intensity on the detection of visual caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on visual caution and warning signals which differ as a function of style and brightness. Interactions of different signals with the surrounding light and the amount of pilot workload. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect a signal, the time to respond to the signal, the accuracy of both detection and response, and a subjective evaluation of the aesthetic value of each of the signals.

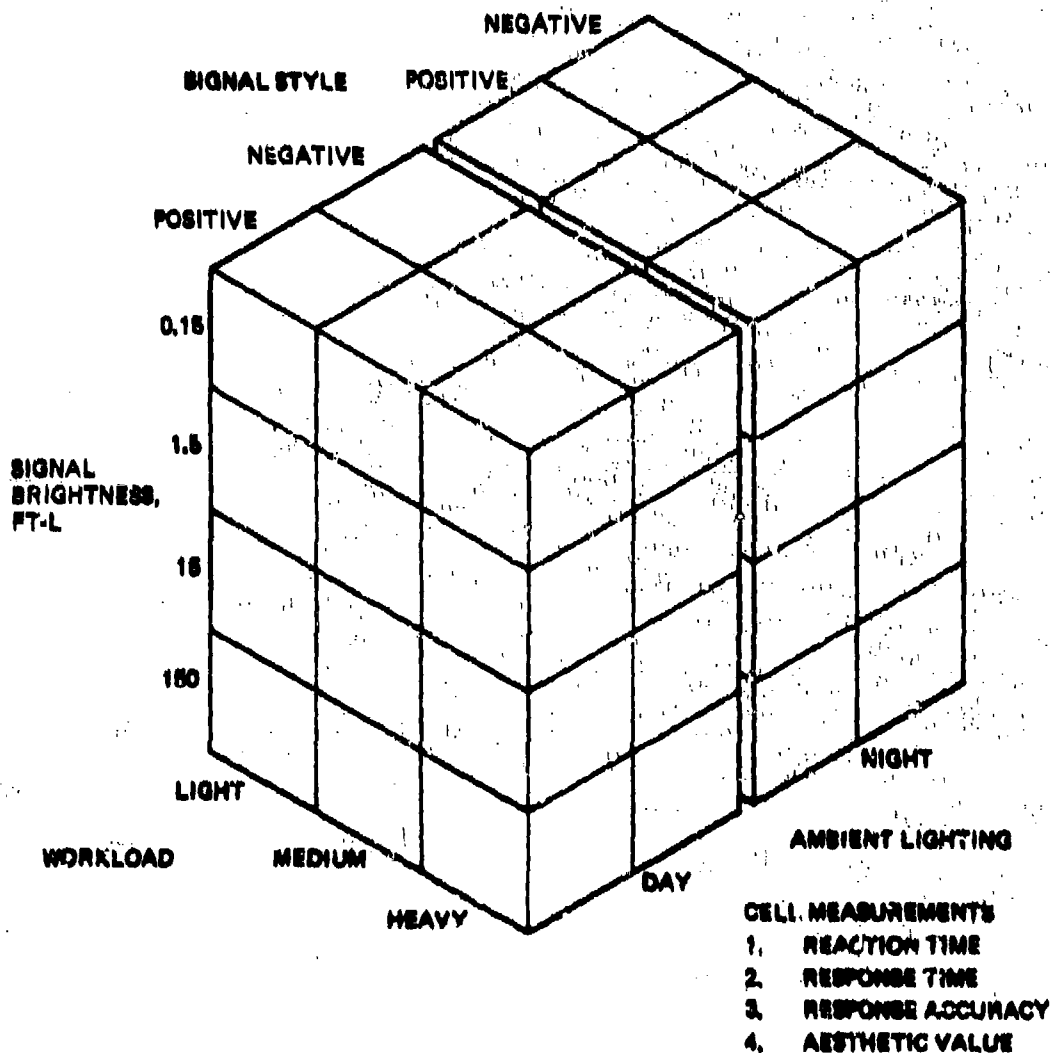
**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection performance in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using two different styles (positive & negative) and four different brightness levels for the signal (0.15 to 150 ft-L). The cockpit environment will also be changed with respect to the ambient lighting (0 to 7000 ft-L).

To simulate the circumstance surrounding the pilot in an actual aircraft environment, the pilots will be assigned flight related tasks (i.e., IFR flight) to accomplish. The workload imposed by these tasks will have three levels (high, medium, low), and the appearance of the caution and/or warning signals will occur simultaneously with the flight tasks.

The data from this study will be used to make recommendations on the selection of style and brightness for caution and warning signal lights to be used under different lighting and workload conditions.

# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
VISUAL SYSTEMS

**VARIABLES:** SIGNAL BRIGHTNESS x SIGNAL LOCATION x FLASH RATE x PILOT  
WORKLOAD

**PROBLEM:** The effectiveness of any visual caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal brightness, signal location, signal flash rate, and pilot workload on the detection of visual caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of brightness, location and flash rate. Interactions of different signals with the amount of pilot workload. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

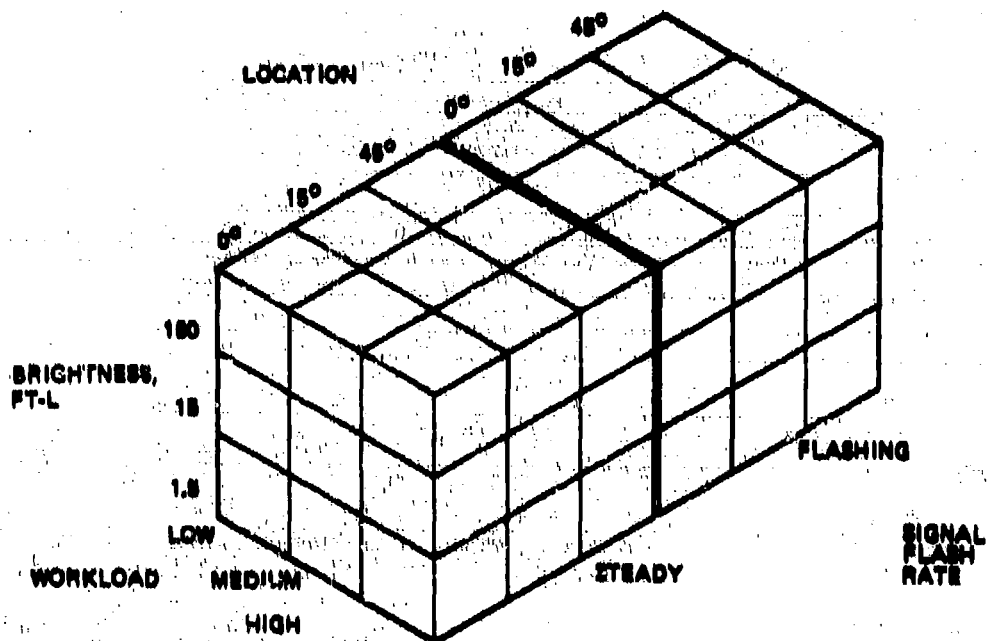
The measurements will describe the time it takes a pilot to detect a signal, the time to respond to the signal, the accuracy of both detection and response and a subjective evaluation of the aesthetic value of the signal.

**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection performance in an actual cockpit environment. The measurements will be taken in a simulated aircraft cockpit using either steady or flashing signals of three different brightness levels (1.5 to 150 ft-L) at three locations (0°, 15°, and 45° horizontal displacement from the pilot's centerline of vision). In an attempt to simulate the circumstances surrounding the pilot in an aircraft environment, the pilots will be assigned flight related tasks (i.e., IFR flight) to accomplish. The workload imposed by these tasks will have three levels (high, medium, and low). The appearance of the caution and/or warning signals and the flight tasks will occur simultaneously.

The data from this study will be used to make recommendations on the selection of location, brightness and flash rate for caution and warning signal lights to be used under different workload conditions.

# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION - VISUAL SYSTEMS

**VARIABLES:** SIGNAL BRIGHTNESS x SIGNAL LOCATION x NUMBER OF DISTRACTING SIGNALS x AMBIENT LIGHT LEVEL

**PROBLEM:** The effectiveness of any visual caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal brightness, signal location, number of distracting signals and the brightness of the ambient light on the detection of visual caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as function of location and brightness. Interactions of different signals with distracting signals and the brightness of the ambient light. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect a signal, the time to respond to the signal, the accuracy of both detection and response, and a subjective evaluation of the aesthetic value of each of the signals.

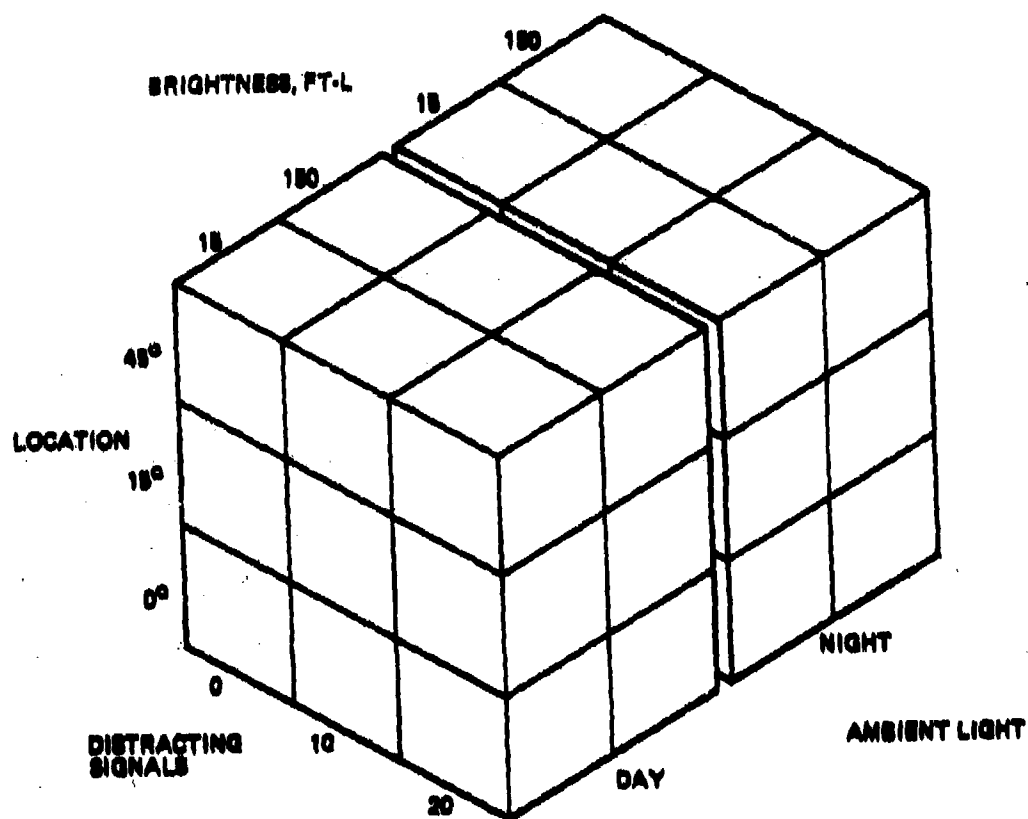
**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection performance in an actual cockpit environment. The measurements will be taken in a simulated aircraft cockpit using signals of two different brightnesses (15 and 150 ft-L) at three different locations (0°, 15°, and 45° horizontal displacement from the pilot's centerline of vision). Distribution will be created by using three different numbers of similar lights (0, 10, 20 lights differing only in color and format) placed in a circular area around the signal with a diameter of 30° visual angle. During the test the cockpit will be changed with respect to the ambient lighting (approximately 0 to 7000 ft-L). In an attempt to simulate the circumstances surrounding the pilot in an aircraft environment, the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to accomplish simultaneously with detecting signals.

The data from this study will be used to make recommendations on the selection of location and brightness for caution and/or warning signals to be used under different levels of ambient lighting and distracting conditions.



# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION - VISUAL SYSTEMS

**VARIABLES:** FALSE SIGNALS x FREQUENCY OF OCCURRENCE x NUMBER OF DISTRACTING SIGNALS x WORKLOAD

**PROBLEM:** The effectiveness of any visual caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of false signals, frequency of occurrence pilot workload and the number of distracting signals on the detection of visual caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals when the surrounding environment is changing as a function of false signals and the number of distracting signals. Interactions of the environment with the amount of pilot workload and the frequency of signal occurrence. Recommendations of signal requirements and design specifications.

**DATA MEASUREMENTS:**

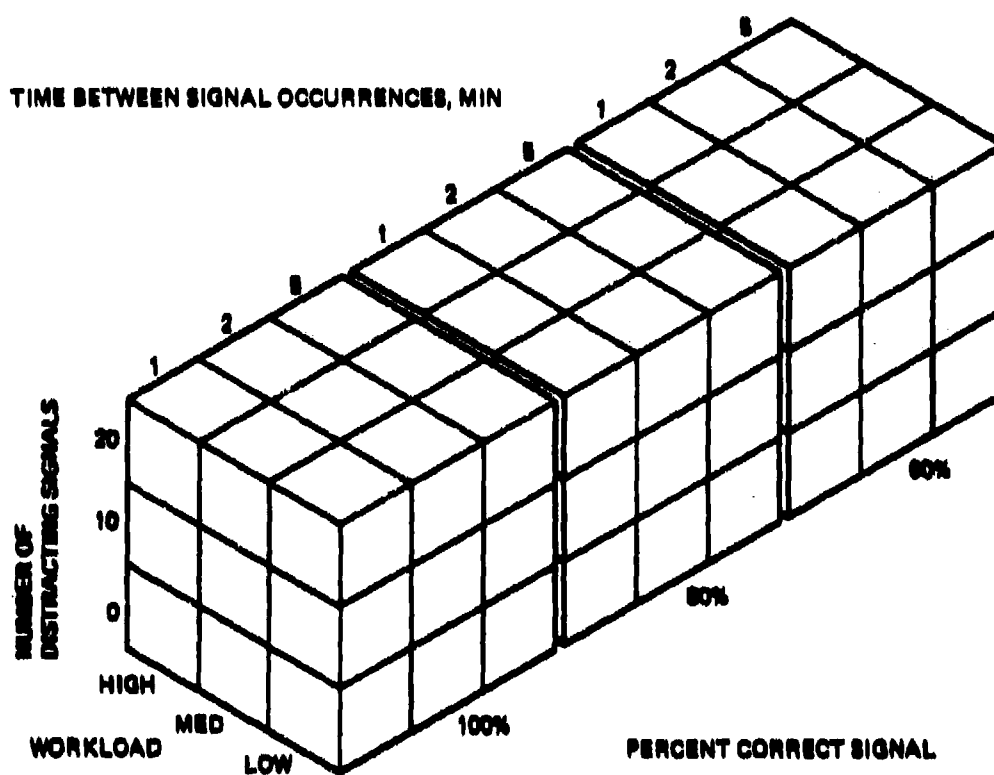
The measurements will describe the time it takes a pilot to detect a signal, the time to respond to the signal and the accuracy of the detection and response.

**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection performance in an actual cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a signal of moderate intensity (50 ft-L). This signal will indicate a valid warning either 100, 80, or 60 percent of the time and will be activated at either 1, 2 or 5 minute ( $\pm 30$  sec) intervals. Distraction will be created by using 3 different numbers (0, 10 and 20) of similar (differing only in color and format) lights placed in a circular area around the signal with a diameter of  $30^\circ$  visual angle. To simulate the circumstances surrounding the pilot in an aircraft environment the pilots will be assigned flight related tasks (i.e., IFR flight) to accomplish. The workload imposed by these tasks will have 3 levels (high, medium and low). The appearance of the caution and warning signals and the flight tasks will occur simultaneously.

The data from this study will provide guidelines for controlling the environment into which a caution and warning signal light is placed and an assessment of the effect of uncertainty and workload on these situations.

# EXPERIMENTAL DESIGN



## SCHEDULE

TESTING		ANALYSIS		
WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5

**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY NON-VERBAL SYSTEMS

**VARIABLES:** NUMBER OF DIFFERENT SIGNALS x FREQUENCY OF OCCURRENCE x  
WORKLOAD

**PROBLEM:** The effectiveness of any auditory caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of the number of different signals, frequency of occurrence, and pilot workload on the detection of auditory non-verbal caution and warning signals.
- III Determine the impact of the findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of number and frequency. Interaction of different signals with the amount of pilot workload. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

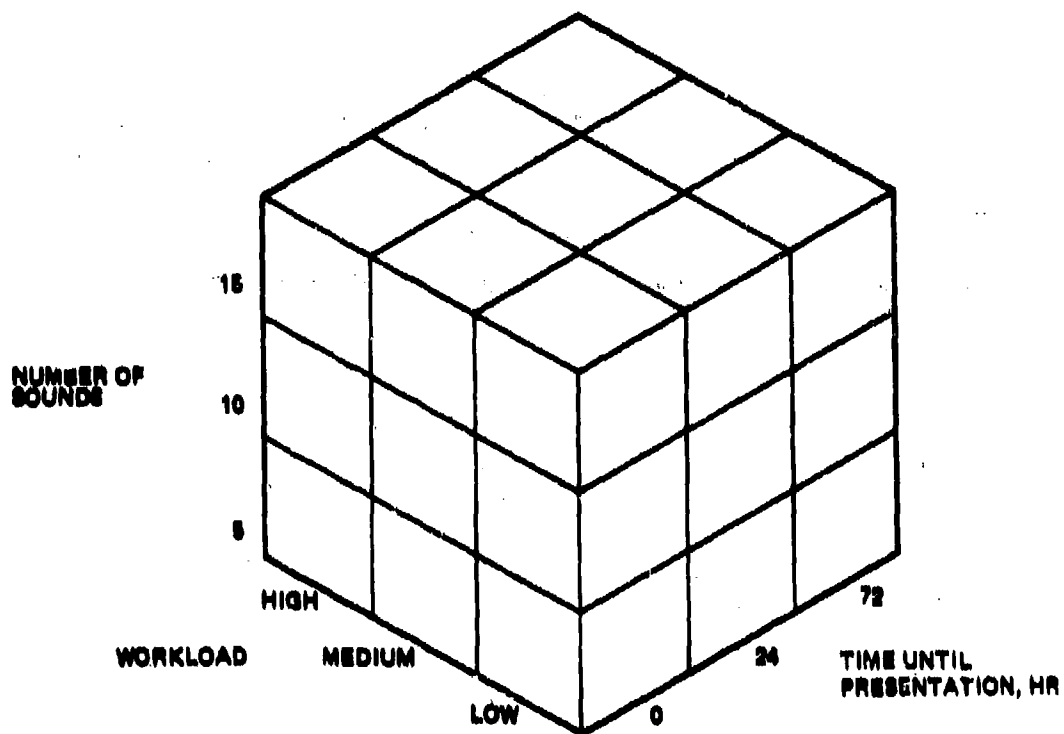
The measurements will describe the time it takes a pilot to detect a signal, the time to respond to the signal and accuracy of the detection and response.

**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection performance in an actual cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a 747 aural warning box to provide discrete caution and warning signals. The pilots will learn to perform specific responses to a number of sounds (either 5, 10 or 15) and will be presented each sound immediately after training for a baseline measure and then again at 24 hours and at 72 hours. To simulate the circumstances surrounding the pilot in an aircraft environment the pilots will be assigned flight related tasks (i.e., IFR flight with ATC) to accomplish. The workload imposed by these tasks will have three levels (high, medium, and low). The caution and warning signals will be presented simultaneously with the flight tasks.

The data from this study will be used to make recommendations on the number of non-verbal auditory caution and warning signals that should be expected to be correctly identified under different workload conditions.

## EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY NON-VERBAL SYSTEMS

**VARIABLES:** INTENSITY x SIGNAL TO NOISE RATIO x TYPE OF BACKGROUND NOISE x  
WORKLOAD

**PROBLEM:** The effectiveness of any auditory caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal intensity, signal to noise ratio, pilot workload and type of background noise on the detection of auditory caution and warning signals.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of intensity and signal to noise ratio. Interactions of different signals with type of background noise and the amount of pilot workload. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

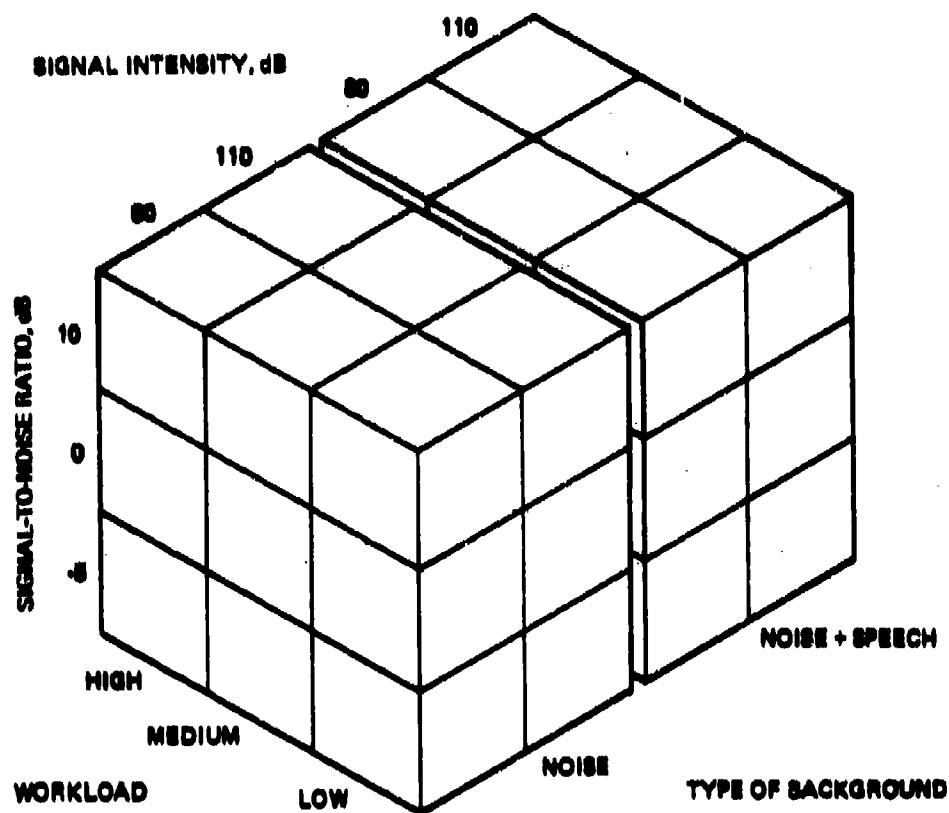
The measurements will describe the time it takes a pilot to detect a signal, the time to respond to the signal and the accuracy of the detection and response.

**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection performance in an actual cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a 747 aural warning box to provide discrete warning signals. Using one standard warning signal two different signal intensities (80 dB and 110 dB) will be tested at three different signal to noise intensity levels (-5, 0, and 10 dB). The cockpit environment will also be changed with respect to the type of background noise (aircraft noise, aircraft noise and speech). In an attempt to simulate the circumstances surrounding the pilot in an aircraft environment the pilots will be assigned flight related tasks (i.e., IFR flight) to accomplish. The workload imposed by these tasks will have three levels (high, medium, and low) and the signals will be presented simultaneously with the flight tasks.

The data from this study will be used to make recommendations on the intensity and signal to noise ratio for non-verbal auditory caution and warning signals which are to be used with different types of background noise and under different workload conditions.

# EXPERIMENTAL DESIGN



## SCHEDULE

TESTING		ANALYSIS	
WEEK 1	WEEK 2	WEEK 3	WEEK 4

**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY NON-VERBAL SYSTEMS

**VARIABLES:** FALSE SIGNALS x FREQUENCY OF OCCURRENCE x LOCATION x  
WORKLOAD

**PROBLEM:** The effectiveness of any auditory caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definite data on the effect of signal location, false signals, pilot workload and frequency of signal occurrence on the detection of auditory caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on the location of the sound in an auditory non-verbal caution and warning system when the surrounding environment is changing as a function of the number of false signals, the frequency of signal occurrence and the amount of workload imposed on the pilot. Recommendations on signal requirements and design specification.

**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal and the accuracy of the detection and response.

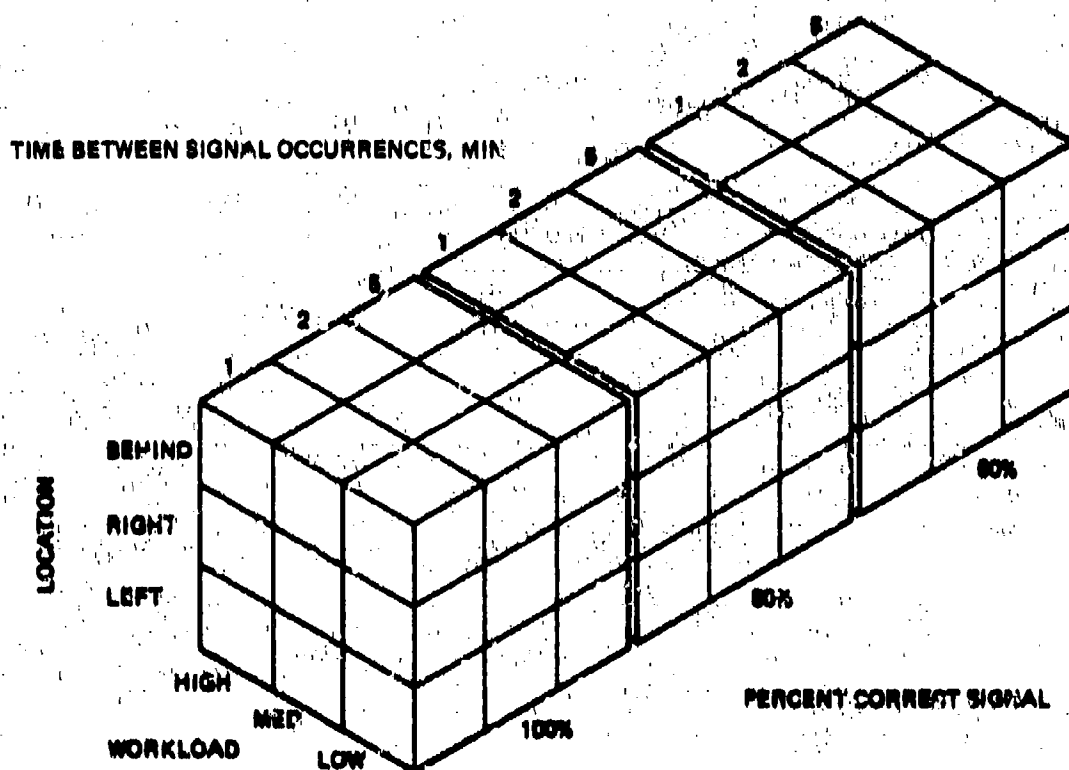
**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection in an aircraft environment. The measurements will be taken in a simulated aircraft cockpit using a 747 aural warning box to provide discrete caution and warning signals. A standard aural warning signal will be presented at three different locations (left, right and behind) and at 1, 2 or 5 minute ( $\pm 3$  sec) intervals. This signal will signify a valid warning either 100, 80 or 60 percent of the time. To simulate the circumstances surrounding the pilot in an aircraft environment the pilot will be assigned flight related tasks (i.e., IFR flight with ATC) to accomplish. The workload imposed by these tasks will have three levels (high, medium and low). The signal will be presented simultaneously with the flight task.

The data from the study will be used to make recommendations on the environment in which discrete aural warnings can be used.



# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY NON-VERBAL SYSTEMS

**VARIABLES:** LOCATION x FALSE SIGNALS x TYPES OF BACKGROUND NOISE x  
NUMBER OF DIFFERENT SIGNALS

**PROBLEM:** The effectiveness of any auditory caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal location, false signals, types of background noise and number of different signals on the detection of auditory and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on the location of sound in a auditory non-verbal caution and warning system when the surrounding environment is changing as a function of the type of background noise, the number of different signals and the number of false signals. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

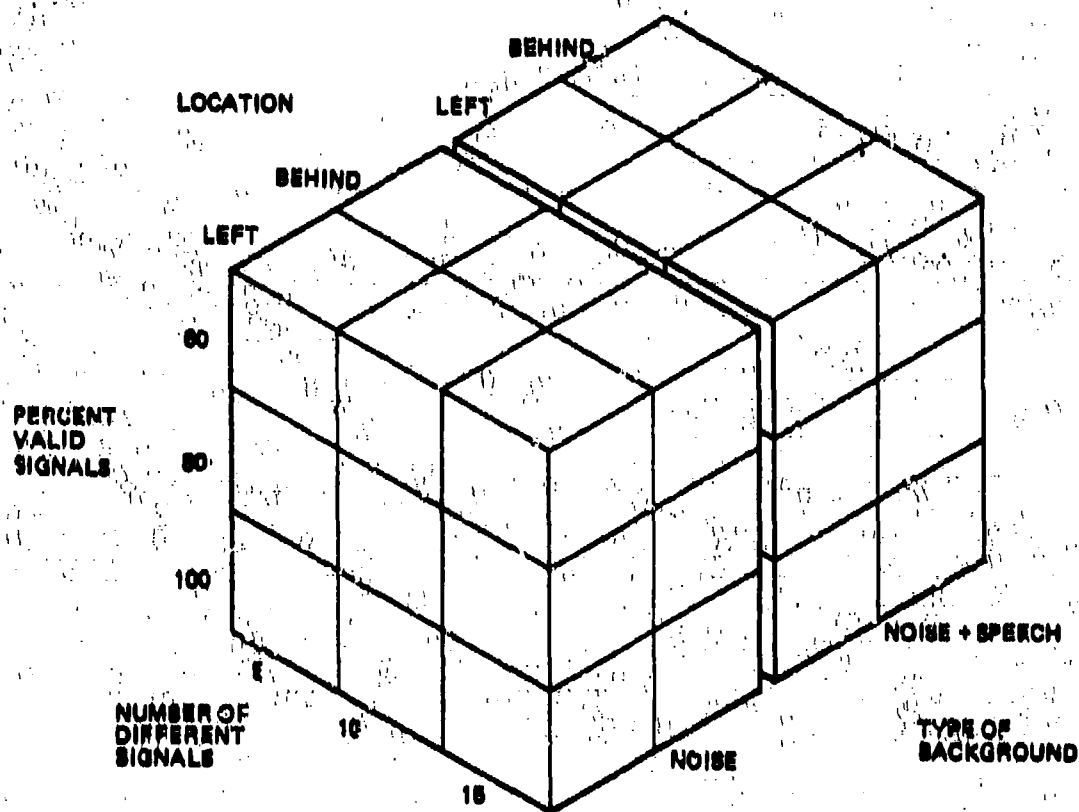
The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal and the accuracy of the detection and response

**TEST APPROACH:**

This effort will develop empirical statistical data describing caution and warning signal detection in an actual cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a 747 aural warning box to provide the caution and warning signals. The pilots will learn to perform specific responses to a number of discrete warning signals (either 5, 10 or 15). The aural warning signals will be presented in two locations (left, and behind) and will be a valid warning either 100, 80 or 60 percent of the time. The background noise will either be aircraft noise or aircraft noise combined with speech. To simulate the circumstances surrounding the pilot in an aircraft environment the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to accomplish simultaneously with detecting the signals.

The data from this study will be used to make recommendations on the environment in which discrete aural warnings can be used.

# EXPERIMENTAL DESIGN



## SCHEDULE

TESTING		ANALYSIS	
WEEK 1	WEEK 2	WEEK 3	WEEK 4

**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY VERBAL SYSTEMS

**VARIABLES:** SIGNAL INTENSITY, SIGNAL CONTENT, TYPES OF BACKGROUND NOISE

**PROBLEM:** The effectiveness of any verbal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definite data on the effect of signal content, signal intensity, and types of background noise on the detection of verbal caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of content and intensity; and the interactions of different signals with the types of background noise. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

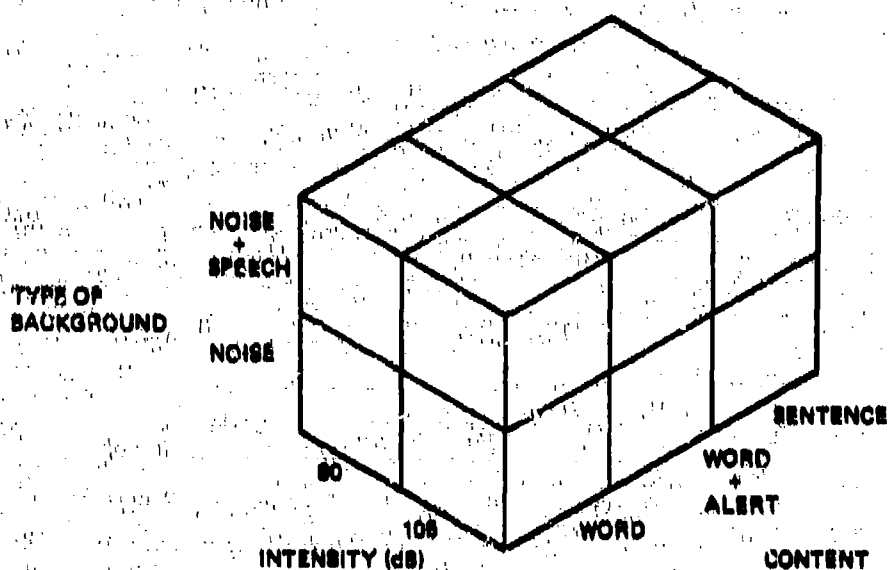
The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, the accuracy of the detection and response and a subjective evaluation of the aesthetic value of the signals.

**TEST APPROACH:**

This effort will develop empirical statistical data describing verbal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a series of messages which will have been previously developed and classified as to their intelligibility. Messages of a medium intelligibility will be presented at different intensities (80 and 105 dB) with the signal to noise ratio being held constant at 15 dB. The messages will be of three types; (1) one or two keywords with short presentation time, (2) the same messages preceded by an alerting signal, and (3) sentences with longer presentation time. The background sound will be either aircraft noise or aircraft noise combined with speech (ATC or weather). To simulate the circumstances surrounding the pilot in an actual aircraft environment the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to accomplish simultaneously with detecting and interpreting the warning signal.

The data from this study will be used to make recommendations on the intensity and content of verbal warnings which are to be used with different types of background sounds.

# EXPERIMENTAL DESIGN



4 WARNINGS PER CELL

## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY VERBAL SYSTEMS

**VARIABLES:** SIGNAL INTENSITY x SIGNAL CONTENT x PILOT WORKLOAD

**PROBLEM:** The effectiveness of any verbal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definite data on the effect of signal intensity, signal content, and pilot workload on the detection of verbal caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of intensity and content. Interactions of different signals with the amount of pilot workload. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, the accuracy of the detection and response, and a subjective evaluation of the aesthetic value of the signals.

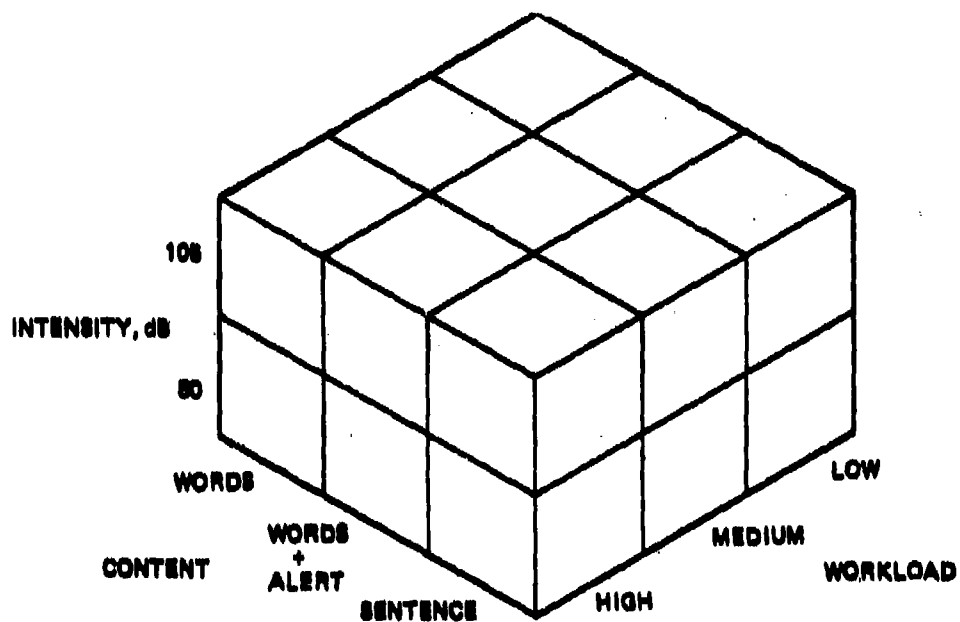
**TEST APPROACH:**

This effort will develop empirical statistical data describing verbal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a series of messages which will have been previously developed and classified as to their intelligibility. Messages of a medium intelligibility level will be presented at either 80 or 105 dB intensity with a constant signal to noise ratio of 15 dB.

These messages will be of three types: (1) one or two key words with a short presentation time; (2) the same messages preceded by an alerting signal; and (3) sentences with the same key words and a longer presentation time. In an attempt to simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilots will be assigned flight related tasks (i.e., IFR flight) to accomplish simultaneously with detecting and interpreting the warning signals. These tasks will impose three levels of workload, (high, medium and low) on the pilots.

The data from this study will be used to make recommendations on the intensity and content of verbal warnings which are to be used under different workload conditions.

# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY VERBAL SYSTEMS

**VARIABLES:** SIGNAL INTENSITY x VOICE TYPE x MESSAGE INTELLIGIBILITY

**PROBLEM:** The effectiveness of any auditory caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning detection.
- II Provide definitive data on the effect of signal intensity, message intelligibility and voice type on the detection of verbal caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of intensity, intelligibility and voice type. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, the accuracy of the detection and response, and a subjective evaluation of the aesthetic value of the signals.

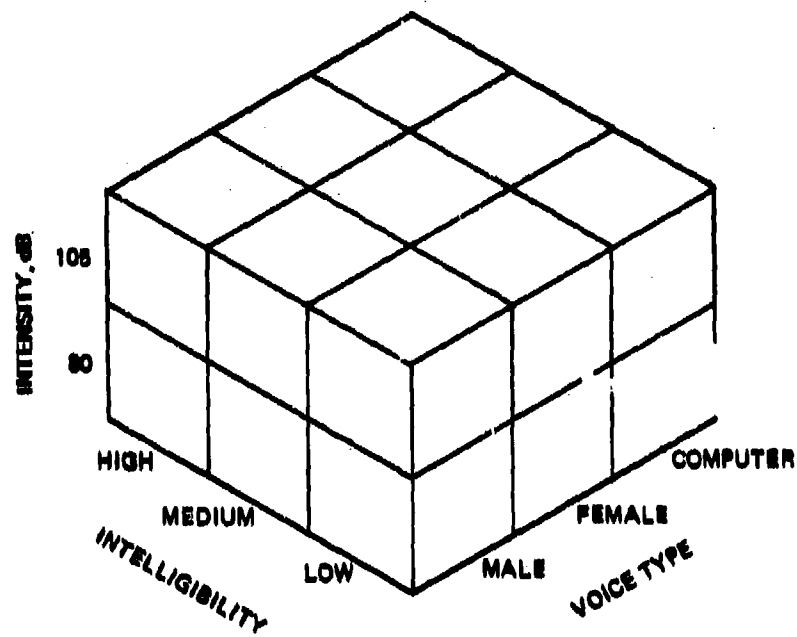
**TEST APPROACH:**

This effort will develop empirical statistical data describing verbal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a series of messages which will have been previously developed and classified as to their intelligibility. Messages of three intelligibility levels (high, medium and low) will be presented at two different intensities (80 and 105 dB) with a constant signal to noise ratio of 15 dB. Each message will be recorded three times, once using a male voice, once using a female voice, and once using a computer generated voice. To simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to perform simultaneously with detecting and interpreting the warning signals.

The data from the study will be used to make recommendations on the intensity, intelligibility and voice type of verbal warnings which are to be used in an aircraft cockpit.



# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY VERBAL SYSTEMS

**VARIABLES:** SIGNAL TO NOISE RATIO x TYPES OF BACKGROUND NOISE x TYPE OF VOICE

**PROBLEM:** The effectiveness of any verbal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of voice type, signal to noise ratio, types of background noise on the detection of verbal caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of voice type and the interactions of different signals with the signal to noise ratio and types of background noise. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

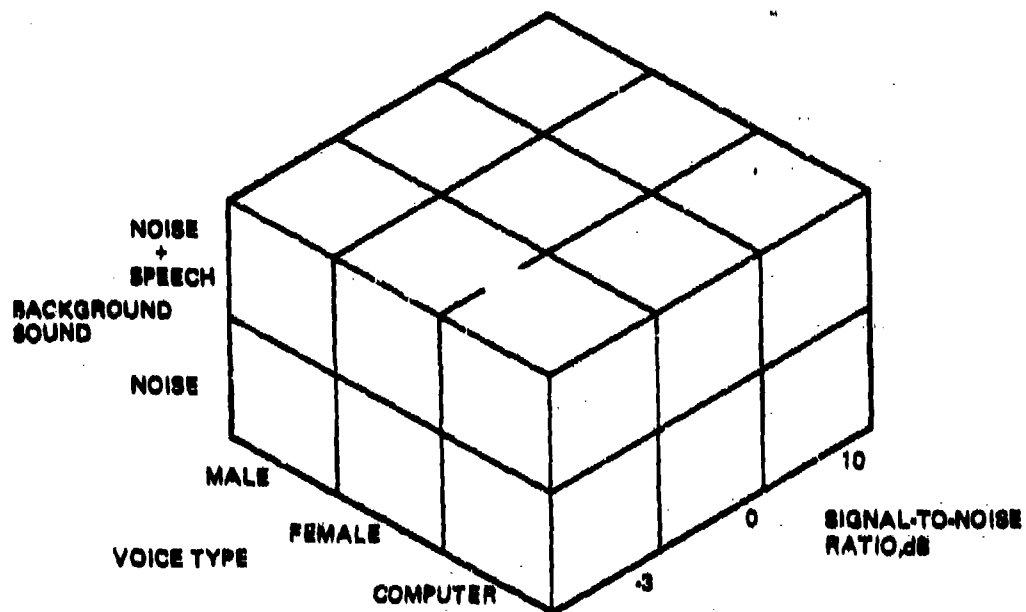
The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, the accuracy of the detection and response, and a subjective evaluation of the aesthetic value of the signal.

**TEST APPROACH:**

This effort will develop empirical statistical data describing verbal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a series of messages which will have been previously developed and classified as to their intelligibility. Messages of a medium intelligibility will be presented at an intensity of 80 dB and the signal to noise ratio will be varied in three levels, (-3, 0 and 10 dB). Each message will be recorded three times, once using a male voice, once a female voice, and once a computer generated voice. The background sound will either be aircraft noise or a combination of aircraft noise and speech (ATC or weather). In an attempt to simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to accomplish simultaneously with detecting and interpreting the warning signal.

The data from this study will be used to make recommendations on the type of voice presentation in a verbal warning system to be used under conditions of different signal to noise ratios and different types of background sound.

# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY VERBAL SYSTEMS

**VARIABLES:** MESSAGE CONTENT x MESSAGE INTELLIGIBILITY x FAMILIARITY  
WITH MESSAGE

**PROBLEM:** The effectiveness of any auditory caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signals detection.
- II Provide definitive data on the effect of message content, message intelligibility, and the pilot's familiarity with the messages on the detection of verbal caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of content and intelligibility and the interactions of different signals with the pilot's familiarity with the messages. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENT:**

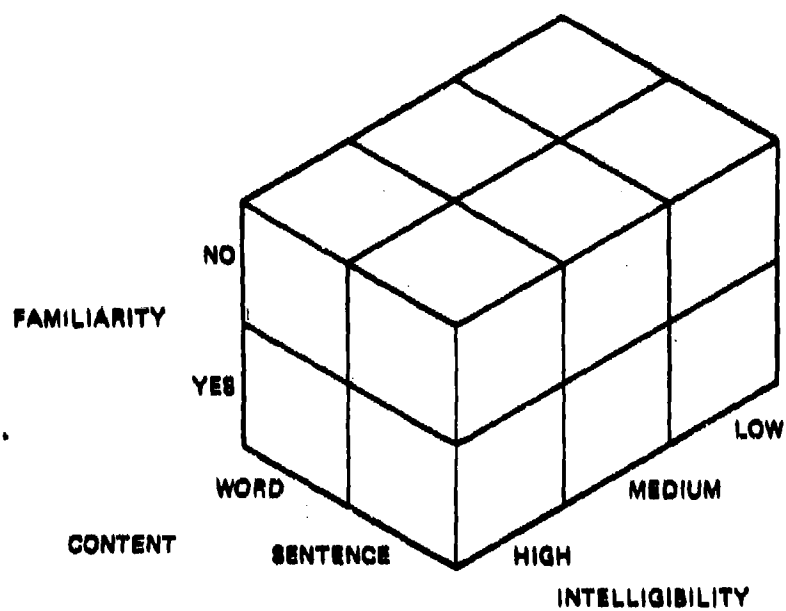
The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal and the accuracy of the detection and response.

**TEST APPROACH:**

This effort will develop empirical statistical data describing verbal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a series of verbal messages which will have been previously developed and classified as to their intelligibility. Messages of three intelligibility levels (high, medium and low) will be presented at an intensity of 80 dB and a signal to noise ratio of 15 dB. These messages will be of two types: (1) one or two key words with a short presentation time; and (2) sentences with the same key words and a longer presentation time. Half of the pilots will review the messages before testing to familiarize themselves with the warnings. The other half will not be introduced to the messages until testing. To simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to perform simultaneously with detecting and interpreting the warning signals.

The data from this study will be used to make recommendations on the content and intelligibility of verbal warnings which are to be used in an aircraft cockpit.

# EXPERIMENTAL DESIGN



## SCHEDULE

TESTING		ANALYSIS	
WEEK 1	WEEK 2	WEEK 3	WEEK 4

**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY VERBAL SYSTEMS

**VARIABLES:** SIGNAL CONTENT x SIGNAL INTENSITY x SIGNAL TO NOISE RATIO x  
NUMBER OF FALSE SIGNALS

**PROBLEM:** The effectiveness of any verbal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal content, signal to noise ratio, and the number of false signals on the detection of verbal caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of content and signal to noise ratio. Interactions of different signals with the number of false signals. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

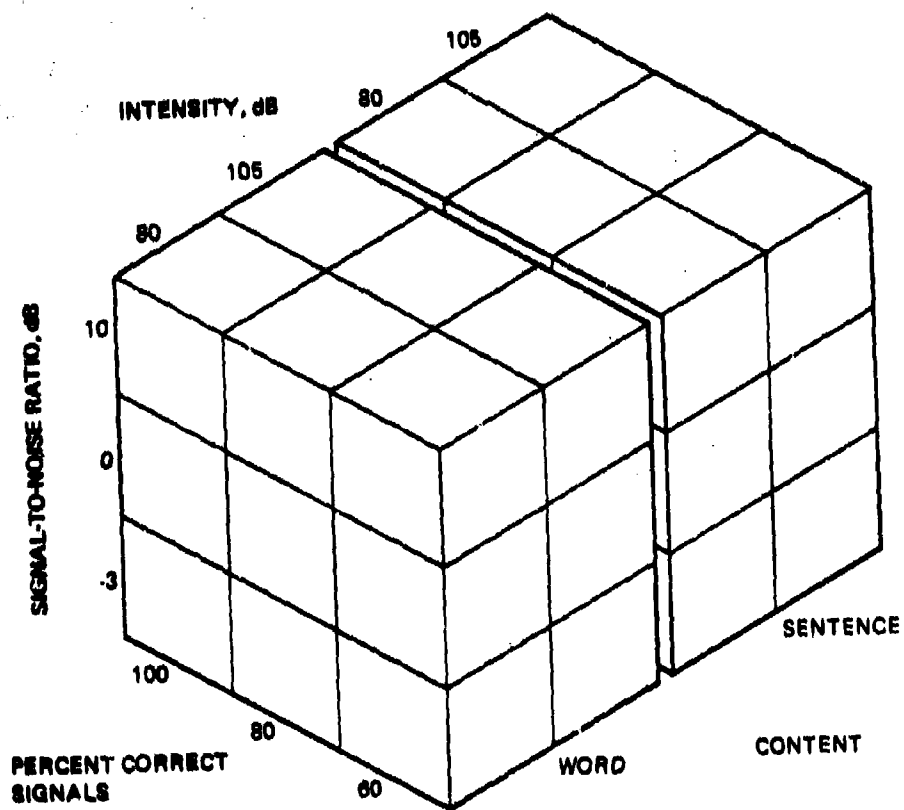
The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal and the accuracy of the detection and response.

**TEST APPROACH:**

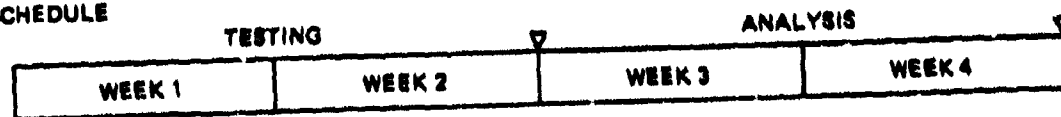
This effort will develop empirical statistical data describing verbal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a series of messages which will have been previously developed and classified as to their intelligibility. Messages of a moderate intelligibility level will be presented at an intensity of either 80 or 105 dB with a signal to noise ratio of -3, 0, or 10 dB. The messages will be of two types: (1) one or two key words with a short presentation time; and (2) sentences with the same key words and a longer presentation time. The signals that occur will be valid signals either 100, 80 or 60 percent of the time. To simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to perform simultaneously with detecting and interpreting the warning signals.

The data from this study will be used to make recommendations on the message content and signal to noise ratio for verbal caution and warning messages to be used when there is a possibility of false signals.

# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
AUDITORY VERBAL SYSTEMS

**VARIABLES:** INTELLIGIBILITY OF MESSAGE x TYPES OF BACKGROUND NOISE x  
FAMILIARITY WITH MESSAGES

**PROBLEM:** The effectiveness of any verbal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal intelligibility, type of background noise and the pilot's familiarity with the messages on the detection of verbal caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of intelligibility. Interactions of different signals with the type of background noise and familiarity with the messages. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal and the accuracy of the detection and response.

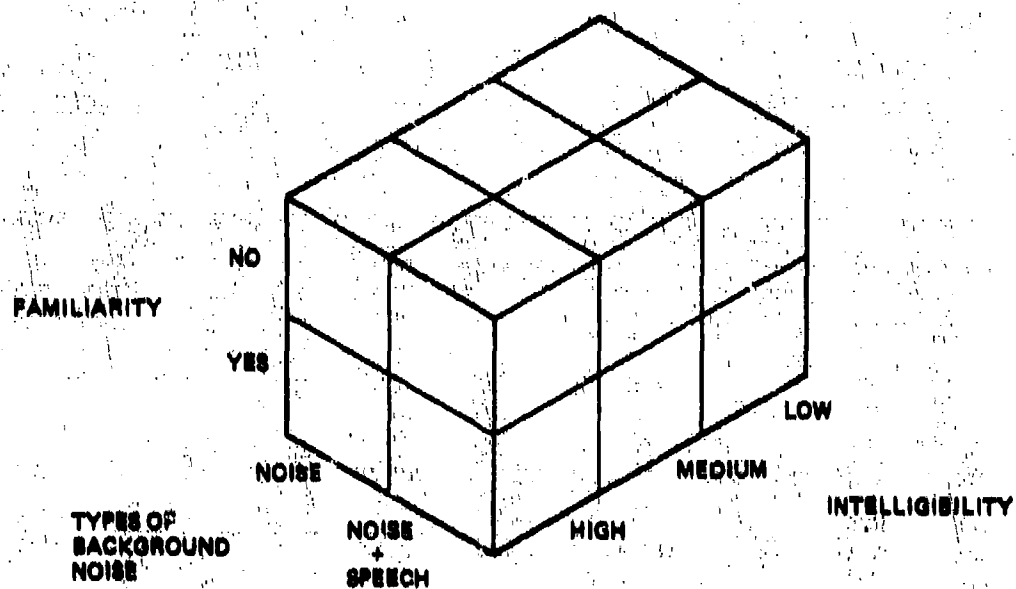
**TEST APPROACH:**

This effort will develop empirical statistical data describing verbal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using a series of messages which will have been previously developed and classified as to their intelligibility. Messages of three intelligibility levels (high, medium and low) will be presented at an 80 dB intensity and a signal to noise ratio of 15 dB. The background sound will either be aircraft noise or a combination of aircraft noise and speech (ATC or weather). Half of the pilots will review the warning messages before they begin the test, thus familiarizing themselves with the content. The other half will not be introduced to the messages until their test. In an attempt to simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned a flight related task (i.e., IFR flight) of medium workload to perform simultaneously with detecting and interpreting the warning signal.

The data from this study will be used to make recommendations on the content and intelligibility needed for messages to be given with different types of background noise.



# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
BIMODAL SYSTEMS

**VARIABLES:** MODAL PRIORITY x SIGNAL LOCATION x DIFFERENTIAL INTENSITY

**PROBLEM:** The effectiveness of any bimodal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal location, differential intensity and which signal comes first on the detection of visual and auditory caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on bimodal caution and warning signals which differ as a function of the modal priority and differential signal intensity. Interactions of different signals with the location of the signals. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

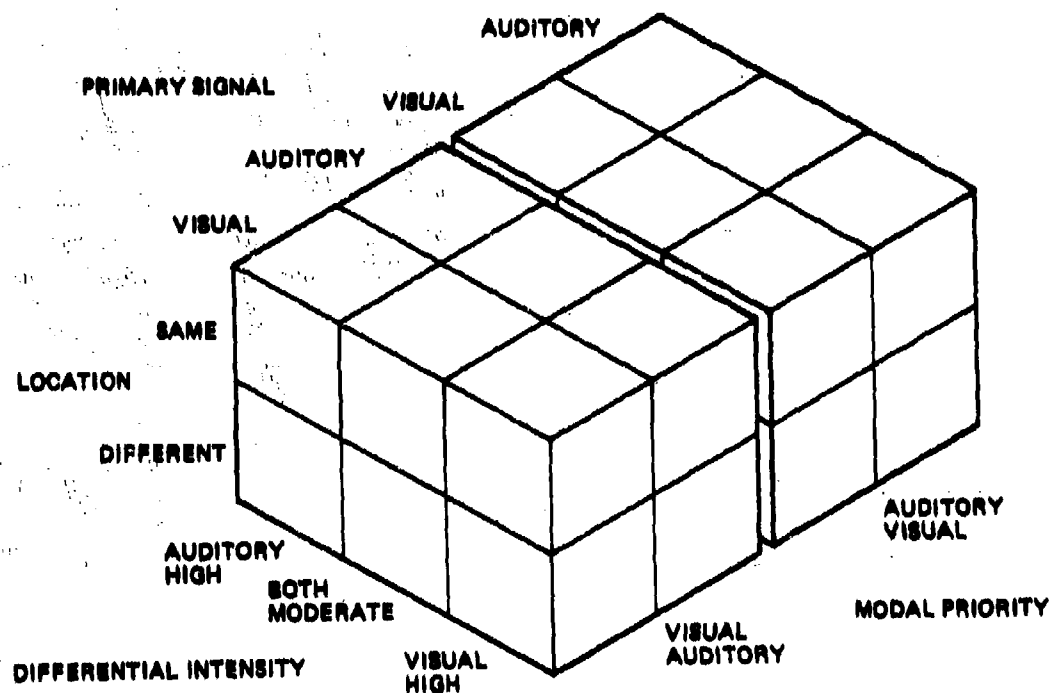
The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, the accuracy of the detection and response and a subjective evaluation of the aesthetic value of the signal.

**TEST APPROACH:**

This effort will develop empirical statistical data describing bimodal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using both visual and auditory warnings. The spatial location of the two signals will be varied so that either the two signals come from the same location or from different locations. The intensities of the two signals will vary such that both signals will be presented at a moderate intensity or either the visual or auditory signal will be at a high intensity and the other at a low intensity. Finally, the order in which the signals will be presented will differ with visual being first half of the time and auditory first the other half. To simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned a flight related task (i.e., IFR flight) of moderate workload to perform simultaneously with detecting and interpreting the warning signals.

The data from this study will be used to make recommendations on modal priority, signal location and intensity for bimodal systems to be used in the cockpit.

# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
BIMODAL SYSTEMS

**VARIABLES:** SIGNAL LOCATION x FALSE SIGNALS x WORKLOAD x PILOT AGE

**PROBLEM:** The effectiveness of any bimodal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal location, false signals, pilot workload and pilot age intensity on the detection of visual and auditory caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of location and number of false signals. Interactions of different signals with the pilot age and the amount of pilot workloads. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

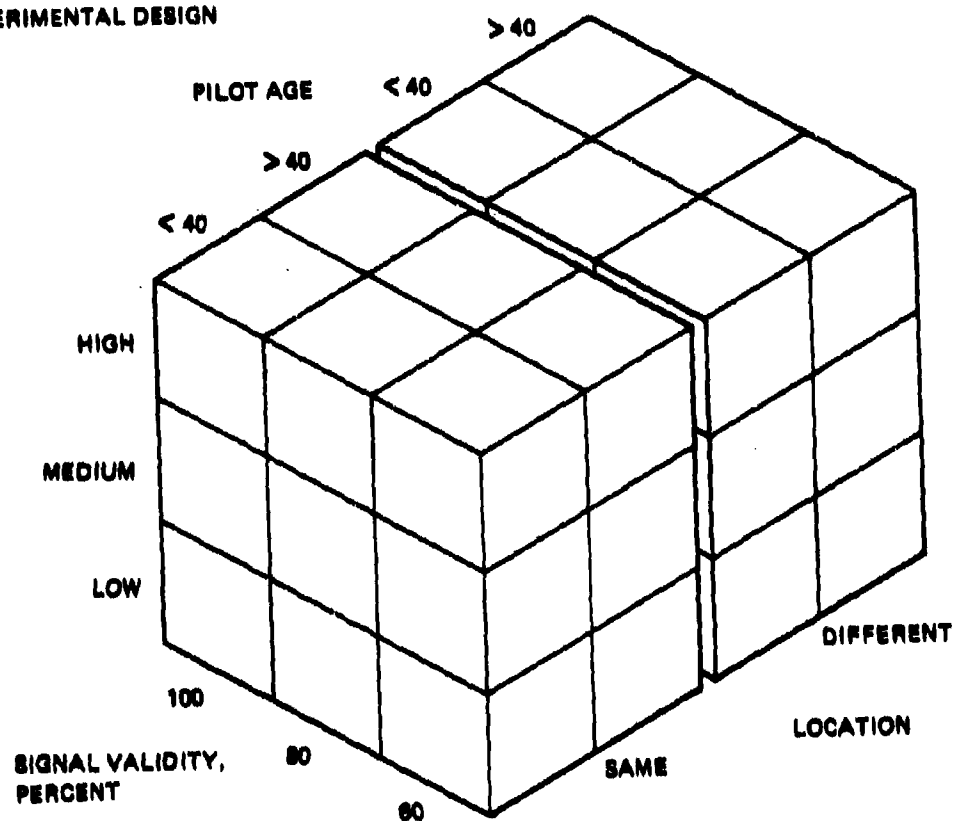
The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, and the accuracy of the detection and response.

**TEST APPROACH:**

This effort will develop empirical statistical data describing bimodal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using both visual and auditory warnings. The spatial location of the two signals will be varied so that they either come from the same place or from at least 90° apart. The auditory signal will always be presented first and be the alerting signal to the primary visual signal. The visual signal will be a valid warning 100, 80 and 60 percent of the time. Pilots will be classified as to their age (over 40 and under 40). To simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned flight related tasks (i.e., IFR flight) to perform simultaneously with detecting and interpreting the warning signal. These tasks will be one of three workload levels (high, medium or low).

The data from this study will be used to make recommendations on signal location for bimodal systems to be used under different workload conditions by pilots in different age groups.

# EXPERIMENTAL DESIGN



## SCHEDULE



**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION -  
BIMODAL SYSTEMS

**VARIABLES:** MODAL PRIORITY x INTERSTIMULUS INTERVAL x SIGNAL DURATION x  
PILOT WORKLOAD

**PROBLEM:** The effectiveness of any bimodal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of the interval between the two signals, which signal comes first, the duration of the signals, and the pilot workload on the detection of visual and auditory caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on bimodal caution and warning signals which differ as a function of the stimulus duration, the modal priority and interstimulus interval. Interactions of different signals with the amount of pilot workload. Recommendations on signal requirements and design specifications.

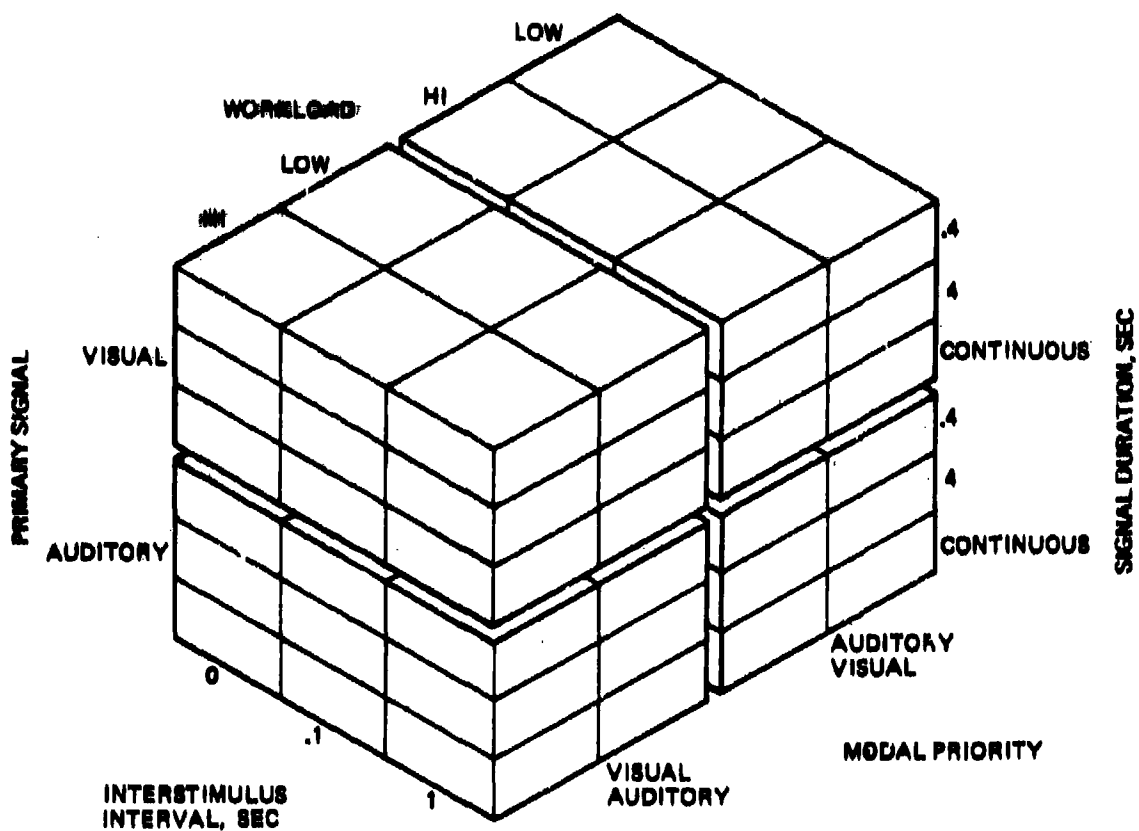
**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, the accuracy of the detection and response and a subjective evaluation of the aesthetic value of the signal.

**TEST APPROACH:**

The effort will develop empirical statistical data describing bimodal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using both visual and auditory warnings. The visual warnings will be lighted signals of moderate brightness presented in the pilot's natural line of vision while the auditory signal will be of moderate pitch and intensity with a signal to noise ratio of 15 dB. The order in which the signals will be presented will be varied, visual first and auditory second or vice versa with three intervals between the signals (0, 0.1 and 1 sec). For half of the pilots, the visual signal will be the primary warning and the auditory signal will be an alert. This relationship will be reversed for the second half of the pilots. Each signal will be present for one of three durations (0.4 and 4 sec or constantly). To simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned flight related tasks (i.e., IFR flight) to accomplish simultaneously with detecting and interpreting the warning signals. These tasks will impose one of two workload levels (high and low) on the pilots.

# EXPERIMENTAL DESIGN



## SCHEDULE



The data from this study will be used to make recommendations on modal priority, interstimulus interval and signal duration for bimodal caution and warning signals to be used under different workload conditions.

**TITLE:** CAUTION AND WARNING SYSTEMS DATA BASE AUGMENTATION - BIMODAL SYSTEMS

**VARIABLES:** SIGNAL CONTENT x PILOT WORKLOAD

**PROBLEM:** The effectiveness of any bimodal caution and/or warning system is dependent on the detection and correct interpretation of the signals by the user. Information is required on the effect of certain variables on detection performance and design constraints produced by these variables.

**TEST OBJECTIVES:**

- I Augment the existing data base of information on caution and warning signal detection.
- II Provide definitive data on the effect of signal content and pilot workload on the detection of visual and auditory caution and warning signals.
- III Determine the impact of these findings on system design and standardization.

**OUTPUT/PRODUCT:**

Comparative pilot performance data on caution and warning signals which differ as a function of content; and the interactions of different signals with the amount of pilot workload. Recommendations on signal requirements and design specifications.

**DATA MEASUREMENTS:**

The measurements will describe the time it takes a pilot to detect the signal, the time to respond to the signal, the accuracy of the detection and response and a subjective evaluation of the aesthetic value of the signal.

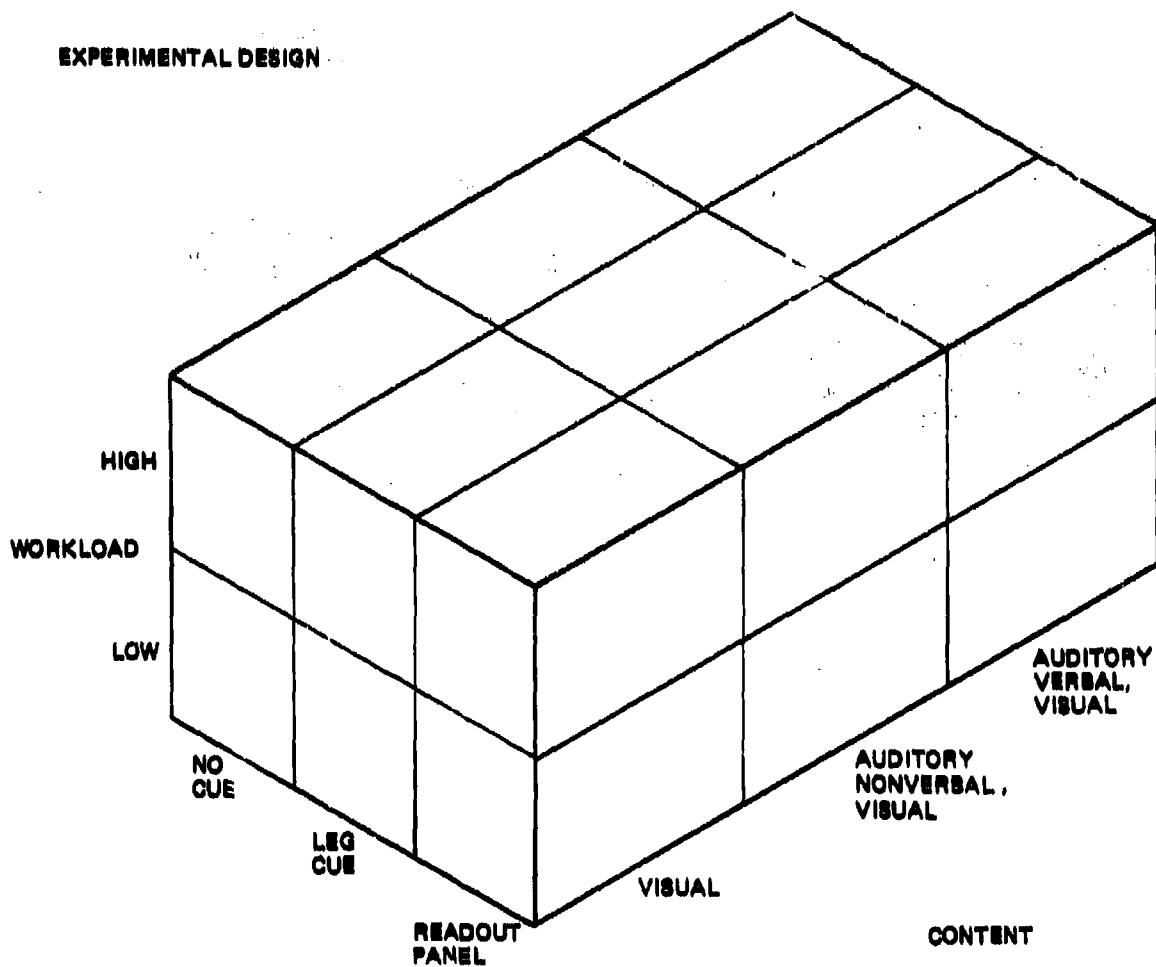
**TEST APPROACH:**

This effort will develop empirical statistical data describing bimodal caution and warning signal detection and interpretation in a cockpit environment. The measurements will be taken in a simulated aircraft cockpit using both visual and auditory warnings. The warnings will have three types of content: (1) visual signal tones; (2) auditory non-verbal signal with visual signal; and (3) auditory verbal signal (sentence) with a visual signal. In order to direct the pilot to the correct annunciator panel for response two types of cueing will be tested, (1) a legend cue on the visual signal and (2) an alphanumeric readout panel. To simulate the circumstances surrounding the pilot in an actual aircraft environment, the pilot will be assigned flight related tasks (i.e., IFR flight) to perform simultaneously with detecting and interpreting the warning signals. These tasks will impose one of two workload levels (high or low) on the pilot.

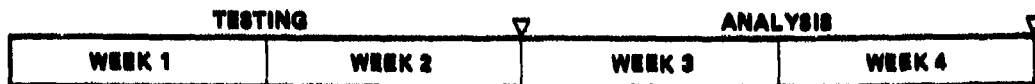
The data from this study will be used to make recommendations on the signal content for bimodal systems to be used under different workload conditions.



# EXPERIMENTAL DESIGN



## SCHEDULE



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